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The Welding Encyclopedia

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A Practical Reference Book on Autogenous Welding

Compiled and Edited by L. B. Mackenzie and H. S. Card of the Editorial Staff of The Welding Engineer, Chicago

Published by

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Chicago, Ill.

THIRD EDITION

Preface

THE experience of and the information collected by the Editors of *The Welding Engineer* made this work possible. It is also true that the splendid spirit of helpfulness exhibited by *The Welding Engineer's* little army of readers is responsible for much of the information contained in The Welding Encyclopedia, and to these loyal friends, we make grateful acknowledgment. It is unfortunate that the information in question is distributed in such a manner that credit cannot be given in each specific case.

To some good friends we must acknowledge valuable assistance given us in the preparation of specific information; among them we find the names of M. Keith Dunham, E. H. Smith, David Ahldin, R. E. Bruckner, Robert E. Kinkead, A. M. Candy, F. J. Maeurer, Stuart Plumley, Ben K. Smith, C. L. Bastian, W. H. Bailey, W. R. Hurlbut, L. I. Grinnell and C. J. Nyquist. To the Chicago and Pittsburg Sections of the American Welding Society we are also indebted for interesting and instructive information by S. W. Miller, D. F. Miner and T. D. Sedwick.

It is the hope of the Editors that the welding industry will find in The Welding Encyclopedia a useful text book. The reader is reminded of the fact, however, that the compilation of a work of this character is no light undertaking and criticisms and suggestions will always be welcomed.

L. B. MACKENZIE.

Chicago. January 27, 1921.

Preface to Second Edition

IN revising the 1921 Edition of *The Welding Encyclopedia* the purpose of the Editors has been two-fold: first, to bring the volume thoroughly up to date; and second, to broaden the scope of the text. The additions to the text will therefore be found to consist of digests of recent developments in welding procedure and practical working instructions covering the welding procedure best adapted to operations most commonly found in the industries which are the largest users of the autogenous welding processes. The chapters dealing with these four processes have been carefully revised and enlarged to provide for the needs of the welding instructor and the student welder.

Further acknowledgment is made of helpful suggestions and information contributed by D. Richardson, F. E. Rogers, B. Heyman, L. Campbell, Jr., R. C. Rohrabacher, E. J. Henke, H. B. Iglehart, E. Wanamaker and C. J. Holsag.

L. B MACKENZIE.

Chicago September 15, 1922.

Preface to Third Edition

IN order to meet the need for a more uniform and systematic method of training oxy-acetylene and electric arc welders, a new chapter devoted to the training of operators has been included in the Third Edition of *The Welding Encylopedia.* The outlines of the two courses of training not only make possible a thoroughly systematic and logical study of each of the processes, but also serve as a guide to the welder who is studying independently. To the casual reader these outlines will also serve as a handy guide to the various classes of welding information which are to be found in other portions of the text.

Other important additions include extensive development which have been made in the welding of tanks and pipes. A number of large plates give the details and specifications of typical constructions, and there are useful additions referring to these constructions to the series of tables. The number of special welding jobs giving details of preparation and handling of the work has been considerably increased.

The purpose of these additions has been to make *The Welding Encyclopedia* keep pace with the growing developments of the industry, and show an increased value to the student welder, the welding instructor, the construction engineer, and the man in the shop.

L. B. MACKENZIE.

Chicago, Sept. 1, 1923.

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THE WELDING ENCYCLOPEDIA

—A—

"A"

Trade name for a flux for cast iron welding. Made by Bierman-Everett Foundry Co., Irvington, N. J.

Abbot Joint

See chapter on "Rail Joint Welding."

Acagine

A mixture of bleaching powder with lead chromate and sometimes barium sulphate; used as a purifier for acetylene.

Acetone (C_3H_6O)

An inflammable liquid of distinctive or ethereal odor and a biting taste. As a solvent agent for acetylene gas it has an absorptive capacity of 24 to 25 volumes acetylene per volume of liquid per atmosphere. It boils at 56° C. One pint of acetone weighs approximately one pound. Experiments conducted by the French Dissolved Acetylene Company show that under ordinary conditions of use and service the initial pressure is increased approximately one-thirtieth for each degree Centigrade rise of temperature. Acetone is used as the solvent liquid in acetylene cylinders. See "Acetylene."

Acetylene

Acetylene is, without doubt, the most important of all the gaseous hydro-carbons used in the gas welding industry. With the introduction of commercial production of calcium carbide, in 1895, the process of gas welding, as we know it today, can be said to have been born, and with the inventions of practical methods for the manufacture of oxygen the development and application of high temperature torches became very rapid, this progress still continuing, and the acetylene still being the leader of all the combustible gases used in the gas welding industry.

Acetylene can be produced by the direct combination of carbon and hydrogen, as well as by various other methods. The only method that has proven to have any practical value is to allow water to re-act upon calcium carbide CaC2, a chemical compound produced by fusing together lime and coke in an electric furnace. The reaction between water and carbide is instantaneous, and as a result, the carbon in the carbide combines with the hydrogen in the water, forming Acetylene, while the calcium combines with the oxygen and water, forming slacked lime, or calcium hydrate.

The calcium carbide and water are brought in contact with each other in generators, either by allowing water to come in contact with an excess of carbide, or, by dropping carbide in an excess of water. The latter, "carbide-to-water" process, has proven itself best suited for the production of large quantities of acetylene, such as used in the welding trade, and practically all generators on the market today for welding purposes are constructed in accordance with this principle.[1] Several devices have been perfected to make the generators automatic, so as to produce acetylene at the same rate as it is consumed at the torch, and stop all generation when the torch is not in use.

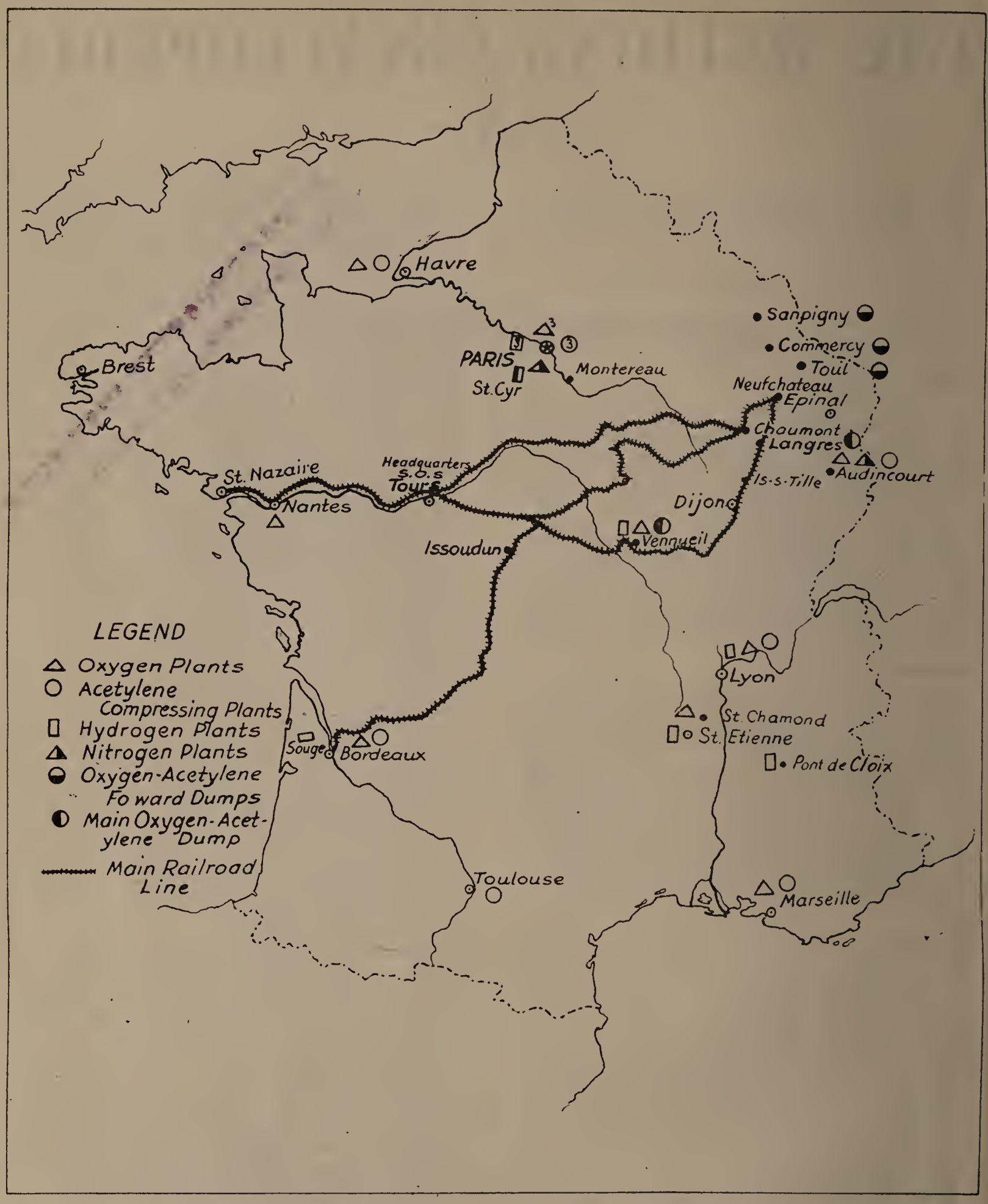
Another differentiation of the generator constructions is based on the pressure carried in the generators when the gas is produced. In the low pressure type a pressure of from 4 inch to 6 inch water column is maintained, whereas in the high pressure type, a maximum pressure of fifteen pounds per square inch is maintained. A still higher pressure can, of course, be produced in the generators, but for reasons that will be explained later, all such attempts should be abandoned, and too intense a warning cannot be given possible "inventors" to keep away from any attempts to construct such dangerous contrivances. The low pressure and the high pressure (also called medium pressure) generators have no separate fields to cover in the welding trade. Under some conditions the low pressure generator is preferable, under other conditions the high pressure type. Each problem has to be studied individually, and the type of generator decided upon from the local conditions. In large plants, where the acetylene is later compressed into cylinders, the low pressure type has proven the best, whereas, in plants from which the gas is piped through long pipelines to numerous welding stations, the high pressure type has proven to possess several advantages, although even in such cases the low pressure generator can be used to advantage, if combined with a compression unit, arranged to deliver the acetylene to the pipeline at a pressure of fifteen pounds per square inch.

Before leaving this brief description of acetylene generators, it might be allowable to express one additional warning to the as yet possibly dormant inventive game. The process for production of acetylene from calcium carbide is very simple, but before trying to simplify existing constructions or attempting any radical departure from the conventional designs be sure to study carefully the nature of carbide, acetylene, and the various constructive designs and materials, otherwise serious accidents are sure to be invited that might result in loss of life and property. If in doubt, confer with The Welding Engineer, or some other authority on the subject.

The chemical structure of acetylene is given in the formula C_2H_2 and shows that two atoms of carbon (atomic weight 12) are combined with two atoms of hydrogen (atomic weight 1.008) or, in other words: Acetylene consists of 92.3% carbon and 7.7% hydrogen. The nearest gaseous hydrocarbon is ethylene C_2H_4, which therefore, consists of 85% carbon, and 15% hydrogen. Acetylene, consequently, is, of all gaseous hydrocarbons, the one that contains the highest percentage of carbon. Add to this that acetylene is the only one of the unsaturated hydro-carbons that possesses endothermic properties (viz: absorbs heat during its production, and liberates heat when it is decomposed) and it is easy to realize the reason for the intense heat that is produced in the oxyacetylene flame (6300°F), which cannot be approached by any other gas known, and is only exceeded by the heat evolved in the electric arc.

The specific gravity of acetylene as compared with air is .9056, from which figure can be calculated the weight of acetylene per cubic foot. For all practical purposes this figure has been accepted to be 69 pounds per thousand cubic feet of pure, dry acetylene at 60° F., which figure expressed differently shows that one pound by weight of acetylene equals 14.5 cubic feet. Under normal temperature and pressure acetylene is without color, and with a sweet, not unpleasant odor and taste. If not purified it has a pungent, nauseating odor that is very easily recognized and detected, even if strongly diluted with air. Under atmospheric pressure the boiling point of acety-

[1] *See "Generators, Acetylene."*



Gas Supply Bases of A. E. F. During the World War.

lene has been established to be 116.3° F. The critical temperature is 98.7° F, and its critical pressure 61.6 atmospheres (905 pounds per square inch.)

Under low pressure and at normal temperature acetylene is a perfectly stable compound; a spark introduced into an acetylene volume under such conditions will not spread any appreciable distance, and its effect confined to the immediate space around the spark. It must be borne in mind, however, that acetylene, like any other combustible gas, becomes explosive if mixed with certain proportions of air, and a spark introduced into such a mixture will instantaneously spread through the whole volume. The range of explosive proportions that is generally attributed to acetylene is from 3% acetylene and 97% of air, to 82% of acetylene and 18% of air. Other authors give the figures 3.35% and 52.30% as lower and upper limits of explosibility. In either case, it proves that the utmost care must be taken to exclude all air from generators and pipelines. and that all constructions must be based on this important requisite.

If generated under a pressure exceeding twenty-five pounds per square inch, or compressed to such a pressure, the acetylene acquires explosive properties that must cause the operator to be on constant guard. If a spark or a sudden shock is introduced into such an accumulation of acetylene under pressure, the dissociation of the gas will travel through the whole gas-quantity. No air is needed to produce such an explosion, as the gas itself is decomposed into its original elements, carbon and hydrogen.

For this reason all generators should be constructed for an absolute maximum generating pressure of fifteen pounds per square inch. so as to eliminate any possibility of dangerous pressure in same. The National Board of Fire Underwriters have specified the above mentioned maximum pressure on all acetylene generators upon the urgent appeal of all acetylene men, that have the welfare of the industry at heart.

Before going into the description of compressed acetylene it might be well to mention here the impurities that are inherent to the commercial grade of calcium carbide, and the methods now used to eliminate same from the acetylene, and, consequently, also from the weld.

The principal impurities that are inherent to the commercial grade of calcium carbide, and which will contaminate the acetylene produced from same are lime dust, sulphur and phosphor combinations, and ammonia. All these impurities are detrimental to a successful operation of the welding torch and to a good weld and should be eliminated from the acetylene. as should also the water vapor that follows the gas from the generator. The lime dust is produced in the generation, and is easily eliminated by the introduction of proper screens of hairfelt or such like. The ammonia can be taken out by leading the acetylene through a water seal, where the ammonia is dissolved and held in the water, while the gas passes on through the pipeline. The most efficient method of eliminating the sulphur and phosphor combinations from the acetylene is to force the gas through a finely divided substance holding some chemical reagent that will form non-gaseous compounds with the sulphur and phosphor combinations. Various reagents have been perfected for this purpose, the most important ones being Heratol, Frankolin, and Catalysol. Each one of them is today used with exceedingly good results, and the acetylene can easily be purified to within a very small fraction of 1%. A test can readily be made to determine the relative purity of the acetylene, by moistening a small piece of litmus paper or white blotting paper with a 5% solution of silver nitrate, and holding this paper in the flow of the gas. Raw gas will immediately produce a dark brown or even black spot on the paper, whereas pure gas will leave the paper perfectly white, even if the moistened paper is held in the gas stream for one minute. The moisture in the gas can be eliminated by passing the acetylene through boxes containing either quick lime or chloride of calcium. Both of these materials have a great affinity for water vapor, and the slightest traces of water can thus be eliminated.

Acetylene, like any other gas, can be compressed. and, if kept sufficiently cool it can even be liquefied. to a colorless, odorless liquid. At an extremely low temperature it has been possible to produce acetylene in solid form.

There is, however, one feature in connection with the compression and liquefaction of acetylene that is of the utmost importance to bear in mind when attempting such work. Acetylene, when compressed, becomes very unstable, and will, under the slightest provocation, completely dissociate into its chemical components. carbon and hydrogen, with an accompanying remarkable increase in temperature and pressure. This property of the acetylene can in part be explained by the chemical structure of the acetylene molecule and in part also by the endothermic nature acquired by the acetylene in its formation.

In the early development of the acetylene industry very little was known about the chemical and physical properties of the acetylene and the gas was compressed into empty cylinders, with little or no precautions taken. This so compressed and even liquefied acetylene was placed on the market, and in spite of some sporadic accidents and explosions, this trade was carried on for a few years. The continued accidents with this gas, however, caused some governments to restrict its use, and finally all civilized countries prohibited the use of liquid acetylene. Compressed free acetylene was still allowed to be used, and it is only quite recently that a universal ruling prohibiting the use of this commodity has been accepted and enforced.

Acetylene had, however, proved itself so superior to other gases that the problem of storing same in an absolutely safe manner was thoroughly investigated. Two French scientists, Claude and Hess, in their research work, established the fact that acetylene would completely dissociate or explode if compressed to a pressure of approximately twenty-five pounds per square inch or more. They furthermore proved that if acetylene under a pressure of more than twenty-five pounds was exploded in tubes of very small diameter, the walls of the tubes absorbed the generated heat so quickly that explosion became confined to the particular spot where the explosion originated.

Basing their work on these facts, Claude and Hess constructed a container with the interior sub-divided into very minute cells, and experiments with containers filled with such porous mass proved that acetylene under pressure could with safety be stored in same. Further experiments have proved that an efficient porous mass can be produced with as high porosity as 80% without jeopardizing the necessary strength of same.

Simultaneously with these experiments Claude and Hess approached this problem of safety storing acetylene under pressure from a different viewpoint.

It is an established fact that all gases can be absorbed to a greater or lesser degree in various liquids, as, for instance. carbonic acid gas in water. Acetylene follows this law of nature, and, in investigating this property of acetylene, Claude and Hess found that the liquid acetone (dimethyl-keton) was able to absorb great quantities of acetylene. They found that at normal pressure and temperature one volume of acetone will absorb twenty-five volumes of acetylene. It was also established that this absorbing power increases in a proportionate rate with the pressure applied, so that for each atmospheric pressure applied, an additional twenty-five volumes of acetylene will be absorbed, and subsequently released when the pressure is reduced.

Another important feature of this acetone-acetylene solution proved to be that the exothermic properties of the acetone counteracts the endothermic properties of the acetylene, and, consequently, the acetone-acetylene solution is to a certain extent immune from a complete dissociation in case an ignition or explosion is introduced into same.

In absorbing acetylene acetone increases in volume, in a proportionate rate to the volume of acetylene absorbed. In an equal manner the acetone decreases in volume when the acetylene is discharged. Consequently, it is seen that in a container holding acetone for absorbing or dissolving acetylene it is necessary to allow for this increase in the volume of acetone. This necessarily means that when the gas is being discharged from such a container a certain space is created, which contains free acetylene under pressure. Therefore, acetone alone in a container does not suffice for a safe storage of acetylene under pressure. By combining the two ideas of a porous mass in a cylinder, and introducing acetone in this mass, Claude and Hess finally solved the problem of storing acetylene under pressure with absolute safety.[2]

After this solution of the problem had

[2] *See "Acetone."*

been accomplished there remained a certain amount of research work to be done in producing the correct commercial application of same. This work has been going on the last twenty years, and continuous progress has been made until today absolutely reliable constructions of acetylene cylinders have been obtained.

The combination of compression and absorption utilized in an acetylene cylinder for the storage of the acetylene makes it very difficult not to say impossible, to measure the available gas-quantity by a simple pressure gauge reading as can be done when dealing with other gases transported and sold under pressure. For this reason another method has been introduced to determine the gas-quantity in an acetylene cylinder at any time, regardless of pressure. The method thus employed simply consists in weighing the cylinder before and after its use, and computing the acetylene consumed from the known weight per cubic foot of acetylene. For work where absolute accuracy is a necessary requisite a correction should be made for temperature, but for all practical applications the above method has proven to be satisfactory.

When the gas is discharged from an acetylene cylinder at certain proportion of the acetone is taken out with the gas in the form of acetone vapor. The more rapidly a cylinder is discharged, the greater is the percentage of acetone vapor in the acetylene. Experience and numerous experiments have proven, however, that if the flow of gas from a cylinder is kept within certain limits, the acetone percentage is so small as to be negligible. The maximum gas flow from an acetylene cylinder should not exceed one seventh of the cylinder's capacity per hour, or, in other words, an acetylene cylinder should not be discharged in less than seven hours actual working time. If the work should require a greater gas-consumption than the above figure it is recommended that two or more cylinders be connected in series to one master regulating valve, all cylinders being turned on together.[3]

All acetylene generator installations should be made in full accordance with the rules and regulations adopted by the National Board of Fire Underwriters, and the instructions issued by this board as well as by the responsible generator manufacturer should be strictly adhered to.

Several sizes of acetylene cylinders exist in the market today, the smallest having a gas capacity of 10 cubic feet of acetylene, the largest ones a capacity of over 2,000 cubic feet. For the welding trade cylinders ranging in capacity from 100 cubic feet to 300 cubic feet have proven to be the most practical, as being easily transportable at the same time as holding enough gas for the average welding job. The maximum permitted charging pressure on all acetylene cylinders has been set to 250 lbs. at 70° F.

The acetylene cylinders used in interstate traffic must comply with shipping container specification No. 8, now in force, issued by the Interstate Commerce Commission. Regulations for shipments of these cylinders have also been issued by this commission, and the enforcement of these specifications and regulations has been given the Bureau of Explosives, No. 30 Vesey Street, New York City.

Acid Sodium Carbonate ($NaHCO_3$)

Bicarbonate of soda, or common baking soda (saleratus). Used as a flux.

"Acme"

Trade name for electrolytic oxygen gas. Made by Acme Oxygen Co., Pershing Road at Racine Ave., Chicago, Ill. See Table of Contents, "Catalog Section."

Adapter

A device provided with a socket at one end in which a carbon or graphite electrode can be secured, and at the other end a wire shaped terminal which can be inserted in a metallic electrode holder so it can be used

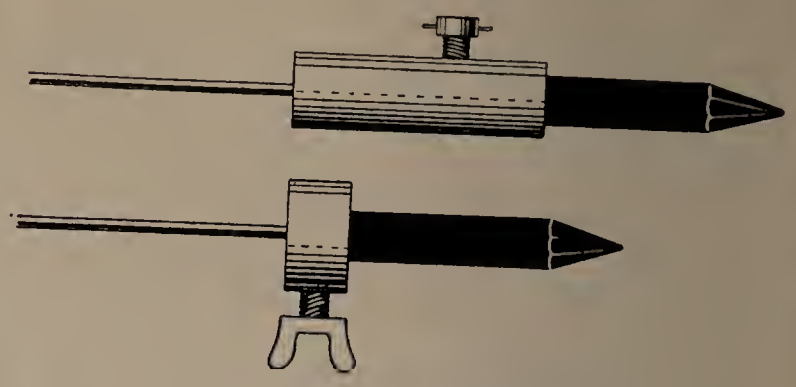


Fig. 1.—Adapter.

for low current graphite electrode welding or cutting. See Fig. 1.

Adapter

A device for connecting a regulator to a tank which has a valve threaded differently than the inlet connection of the regulator.

Adding Material

The filler rod used in welding when the metals to be joined exceed a certain thickness. Also called welding rod and welding wire. For table of correct sizes of filler rods see under "Welding Rods and Wire."

Adhesion

A condition in a weld which results from imperfect amalgamations of the edges to be joined. This condition is sometimes caused by melting down the top of the V on to metal not yet melted and it is also caused by the presence of oxide in the welded seam. Oxide is caused by the adding of molten metal on to metal already solidified, or to the lack of liquifaction in the molten bath constituting the weld. See "Fusion".

"Adjustoglass"

Trade name for goggles for oxy-acetylene welding and cutting. Made by Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. See Table of Contents, "Catalog Section".

"Admiral"

Trade name for welding and cutting torches, regulators and supplies. Made by Admiral Welding Machine Co., Kansas City, Mo.

"A. E. F."

Trade name for electric resistance welding machinery. Made by American Electric Fusion Corp., 972 Montana St., Chicago, Ill.

"Aeroil"

Trade name for preheating torches, kerosene torches, burners and brazing outfits. Made by Aeroil Burner Co., Inc., Union Hill. N. J.

"A. G. A."

Trade name for welding and cutting torches. Made by American Gas Accumulator Co., Newark, N. J.

Agitator

A revolving paddle in an acetylene generator, which stirs up the residium before discharging it.

"Airco"

Trade name for oxygen, acetylene, nitrogen, argon and other atmospheric gas products, also welding and cutting apparatus and supplies. Made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, "Catalog Section".

"Airco-Davis-Bournonville" ("Airco-D-B")

Trade name for welding and cutting torches, regulators, supplies and accessories, acetylene generators, specially designed machines for automatic welding and cutting, etc., formerly made by Davis-Bournonville Co., Jersey City, N. J., made by Air Reduction Sales Company, 342 Madison Ave., New York, N. Y. (Air Reduction Sales Company and Davis-Bournonville Company were

[3] *See "Cylinders."*

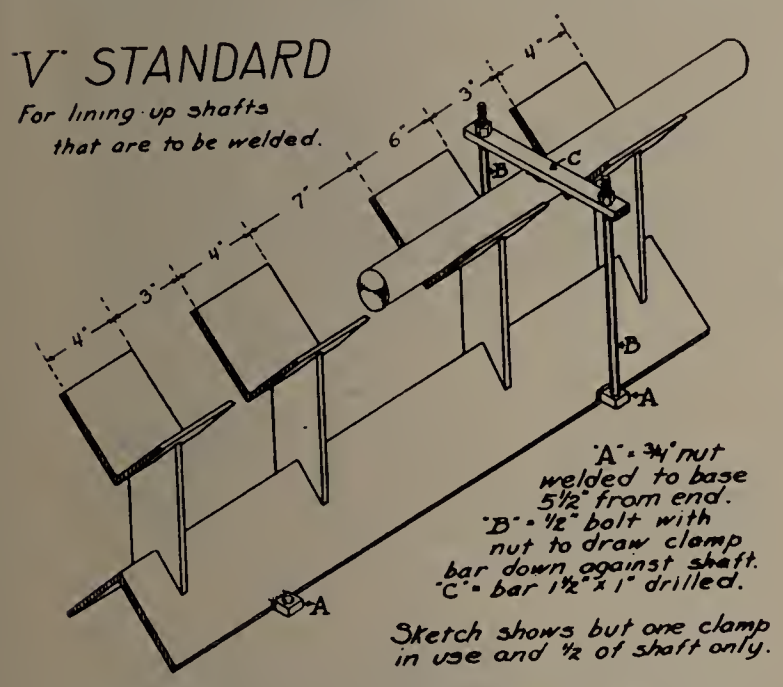
merged on March 17, 1922.) See Table of Contents, Catalog Section.

"Ajax"
Trade name for rail grinders and electric arc welding machines, taking current from trolley wire. Made by Railway Track-work Company, 3132 E. Thompson St., Philadelphia, Pa.

"Albex Bifocals"
Trade name for goggles. Made by Wm. C. Adams, 332 Boylston St., Boston, Mass.

Alignment
State of being in line.

Strange as it may seem many welders particularly those doing odd jobs, line up shafts and bars by eye before welding the broken parts together. They then trust to straightening to produce a good job. Such rough and haphazard methods are not only undesirable but unnecessary. This is especially so when one can easily make an accurate



Home Made Device for Securing Alignment

and serviceable V standard from scrap material. The only cost of such an outfit is an hour or so of labor and the small amount of gas that is used.

Obtain a piece of 4"x¼" angle iron 7 or 8 feet long. Any size angle iron would do, but iron of the dimensions given will make a standard of convenient weight and size.

Cut off two 30-inch lengths. Then cut four plates 10 inches long and 4 inches wide. Cut these to a V at each end and weld to one of the angles as shown in the sketch. After these plates are welded into place, take the other angle and weld it to the plates or legs in the same manner. This angle, which is the V, is now cut into sections leaving spaces for welding or cutting. The spaces for the legs run two inches, seven inches, twelve inches, eight inches with two inches clear at the extreme right.

Alloy
A mixture of two or more metals, the union of which produces what may be described as an alloy. Tungsten steel, for instance, is an alloy.

A union, possessing metallic properties, of two or more metallic elements, or of metallic and non-metallic elements, which are miscible with each other, at least to some extent when molten, to form a homogeneous liquid and do not separate into distinct layers when solid. Such combinations when cold may consist of mechanical mixtures, eutectics or eutectoids, solid solutions, or chemical compounds, one or more of which may exist at the same time.

"Allweld"
Trade name for an aluminum solder. Made by Alloy Welding Products Co., 50 Church St., New York, N. Y.

Alpha Brass
A copper-zinc alloy with a copper content greater than approximately 64 per cent. It is composed of but one type of crystals all of which are of the same composition.

"Al-Solder"
Trade name for an aluminum solder for work on sheet aluminum. Made by The Rohde Laboratory, 17 Madison Ave., New York, N. Y.

"Alternarc"
Trade name for arc welding machines. Made by Electric Arc Welding and Cutting Co., Newark, N. J. See Table of Contents, "Catalog Section".

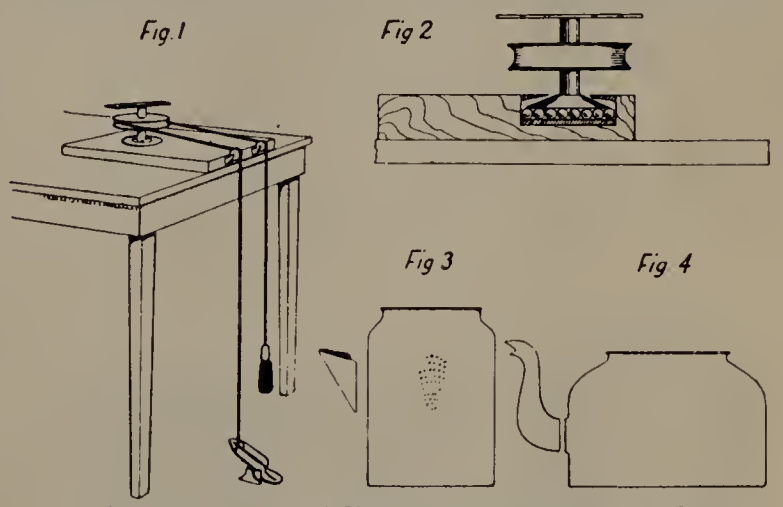
Aluminothermic Process
See "Thermit".

"Aluminox"
Trade name for cast aluminum welding rods and aluminum flux. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

Aluminum
See chapter on acetylene welding. Also see under Sheet Aluminum Welding, Aluminum Kitchen Utensils, Crank Cases, etc.

Aluminum Kitchen Utensils

Aluminum is an ideal metal for such utensils because of its comparatively low cost, its lightness, its non-rusting qualities

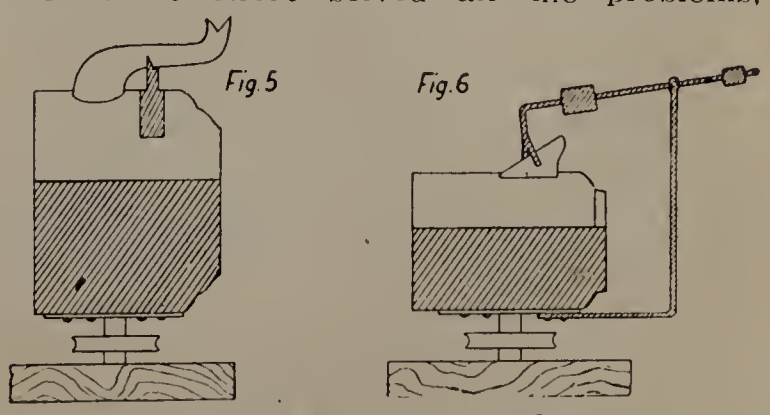


Set-up for Welding Aluminum Utensils.

and its fine appearance. Consequently, it is very popular.

Two of the most indispensable kitchen utensils have been considerably improved by simple welding operation. They are the teakettle and the coffee percolator. These were formerly made by "clinching" the spout to the body, a method that produced the necessary watertight joint but left a tiny crack which in a short time took the appearance of a small black line around the seam. It could not be kept absolutely clean.

For several years the "clinched" spout has been replaced by the welded spout, and the production of the latter has been developed to the point where the appearance of the finished article leaves nothing to be desired. It was not an easy process at the start, for sheet metal has a strong tendency to warp under the influence of the welding flame, and aluminum in any form is easily spoiled by the application of too much heat. Persistent effort solved all the problems,



Holding the Work in Place.

however, and today the dealer can display to his trade a kettle or percolator which shows not the slightest trace of a joint be-

tween the spout and the body. In fact, there is no joint—the spout and the body have become a single piece under the magic of the oxy-acetylene flame. If the spout is banged against the oven of the gas stove, or against the faucet over the sink, it cannot break loose, for there is no place where a break can start.

Welds Finished But Not Polished.

The welding table (Fig. 1) is equipped with a revolving stand to which can be fitted suitable jigs for holding the parts in place for the welder. This revolving stand (shown in detail in Fig. 2) twists back and forth on ball bearings so that its motion is very smooth and easy. Motion is controlled by a fixed pedal and a counterweight. This easy motion is an important factor in securing perfect welds, for if the stand should stick and then jump the metal would be burned through in spots and portions of the seam would have to be gone over twice.

Appearance of Joints After Buffing and Polishing.

Manganese sheet aluminum is used in the manufacture of a popular brand of kitchen utensils. It is claimed that a small quantity of manganese stiffens the utensils so they will not bend or buckle easily but are hard, dense and rigid. The filler rod used for welding them is a rolled aluminum wire.

Figures 3 and 4 show how simply the percolators and kettles are prepared for welding. The percolator spout is stamped and bent to fit snugly against the body, and the hole in the body of the kettle is flanged outward slightly so that the spout fits over it. A holding jig for each utensil is made by cutting a similar utensil in half and bolting the piece to the revolving stand. An arm holding a weighted fork (Fig. 5) provides sufficient pressure to keep the percolator spouts in place, and the kettle spout is held by a light support underneath (Fig. 5). A powdered flux dissolved in water is used to prevent oxidation. The welder uses a small torch and adjusts the flame so that it is slightly carbonizing, dips his wire into the flux solution, brushes the seam and the wire with the flame, and starts to weld the metal directly before him. As soon as the fusion starts he depresses the pedal and the entire seam passes under the flame. A quick pass with the flame over the end of the seam and the welder is ready for another piece. There is no warping or buckling, nor any ridge of added metal, just a thin dark film of slag over the weld, and a slight discoloration where the flame has played over the metal. Fig. 7 gives a good idea of the appearance of a percolator and a kettle as they come from the welder. A few seconds are required for "buffing up" and the joints then have the smooth polished appearance shown in Fig. 8. The success of work which is being handled in this way is due partly to skill in adjusting and handling the flame, and partly to the ingenious holding devices which cause the work to move along under the flame. Some factories use a set-up which gives the welder four or five pieces to work on on his table, so that revolving the table simply brings a new piece of work to the torch, but this makes it necessary to "crawl" around the work with the torch, so the operation is not as smooth and the results not so satisfactory.

Amalgamation

The blending or mixing of different metals.

"American"

Trade name for welding and cutting torches. Made by American Welding Co., Chicago.

"American"

Trade name for oyxgen and acetylene regulators. Made by Alexander Milburn Co., Baltimore, Md.

American Bureau of Welding

See under "Associations."

American Welding Society

See under "Associations."

Ampere

Unit of measure of quantity of electrical current.

"Anaconda"

Trade name for copper welding rods. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, "Catalog Section."

Angle

The amount of opening between two intersecting lines or surfaces. Angles are commonly measured in degrees, one degree being 1/360 of a complete revolution. The symbol used is a small circle placed to the right of the upper portion of the figure indicating the number of degrees. Thus: 90° —ninety degrees. For the angles used in bevelling parts to be welded, and methods of securing these angles see "Bevel".

Annealing

The process of heating or soaking in a furnace. Most welds would be improved by annealing, as not only is the metal in the actual weld improved, but the metal adjacent to the weld as well. This is particularly true of castings. Annealing not only improves the added metal and adjacent area, but tends to remove any inherent strains which may have originally existed in the casting, or which may have been set up because of the welding operation.

It is safe to say that no welded structure is as strong as the original pieces unless it is subsequently annealed. Somewhere, either in the weld itself or in the adjacent metal, there will be a weak spot, not necessarily weak enough to destroy the usefulness of the structure but nevertheless somewhat weaker than the original metal. How far annealing will serve to remove this weakness is brought out in the following extract from a paper read by Mr. T. D. Sedwick before The American Welding Society, Chicago Section:

Investigation on various welds has shown that in the majority of the cases, especially in certain classes of material, the welding heat or the process of preheating has af-

fected the metal in the sections being welded, this effect being in the nature of a transformation of the physical structure of the steel, and in case of localized high temperatures, the main body of the material absorbing the heat so fast that there resulted a quenching action on the heated

Fig. 1.—How Etching Brings Out Hardened Areas.

metal. In the majority of the instances the extreme hardening action will be localized near the surface, immediately adjacent to the added metal. In some cases of preheating, it has been shown that the high temperature causes a change in the physical

Fig. 2.—Failed Piston Rod.

structure of the metal, and while it is not usually so localized as in the case of the action of the welding heat alone, at the same time certain thermal stresses are set up, these stresses being in addition to those created by the heat generated by the welding process. These conditions have been found in material of thick sections where the heat would not be readily absorbed throughout the section, and where the chemical content, especially the carbon, was such that it rendered the metal readily susceptible to structural changes, resulting in a hardened condition.

Fig. 3.—Annealing Has Removed Hardened Area.

In regard to the tests mentioned: A great many of these were made to develop illustrations for the parties concerned, particularly the practical shopmen, that proper annealing in the majority of the cases should be done after the weld has been completed and that a thorough annealing would improve the physical condition of the metal, thereby causing it to render better service, this thorough annealing to be made by placing the metal in a furnace and annealing it in the proper way by giving it a soaking heat and

Fig. 4.—Metal Added After Preheating.

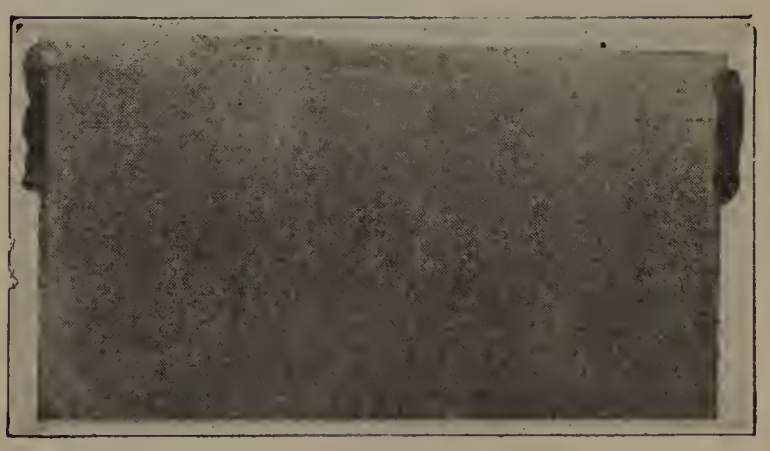


Fig. 5.—After Annealing Piece in Preceding Photograph.

then cooling it so that the whole mass could adjust itself to a uniform condition throughout. The idea of causing a self or automatic annealing to take place by preheating is going at the proposition backwards and trusting to luck that we have not done more damage than good. In order to relieve the shrinkage strains which might be set up in certain sections, it is necessary at times to preheat to take care of these shrinkages during the cooling after welding, but after this has been done, we follow out a thorough annealing program. In

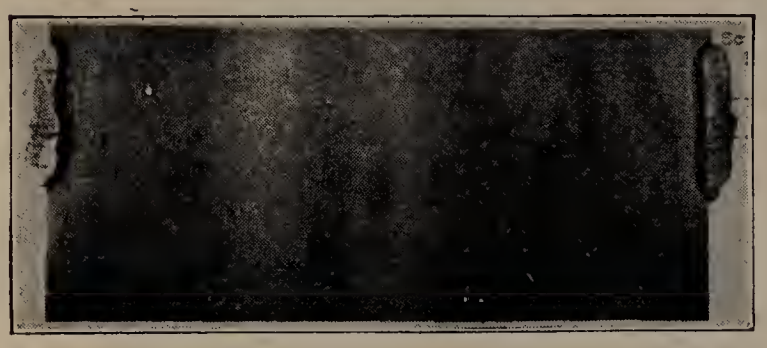


Fig. 6.—This Was Preheated in Blacksmith Furnace.

this way any strain or hardened condition that has been set up by preheating, or by the welding heat, will be eliminated and if such precautions have been taken, we then have a product whose service depends mainly on the quality of the material in the weld, and the perfection of the weld as a weld.

In preheating with a torch of any kind, there are certain zones in this torch flame that are of a higher temperature than others, and in view of the fact that it too often happens that a sufficient length of time is not taken in preheating to permit a soaking heat to be given to the steel, more or less localized heated areas are produced and, as stated before, these in turn will do injury by multiplying the thermal stresses which were not eliminated during the subsequent period of cooling.

In the majority of the shops, especially the larger shops where special annealing furnaces have not been installed, there are always some furnaces of sufficient size in

Fig. 7.—Even Structure Secured by Annealing.

which at least the smaller castings and forgings could be annealed and this annealing could be done at a comparatively low cost; for instance, at the close of the day, as space is being left unoccupied by the regular work of the shops, the welded material could be placed in the furnace and without any material increase in the cost of fuel be annealed over night. This plan would not check production of the regular work.

In regard to the subject of annealing in general: Too little attention is given to this point, even in cases where no welding is done. In reclamation plants where old material is re-worked, for instance, a worn out or failed forging will be re-forged, either into a forging of a smaller size of the same class or may be forged into other classes of forgings. When originally forged there may have been set up thermal stresses in

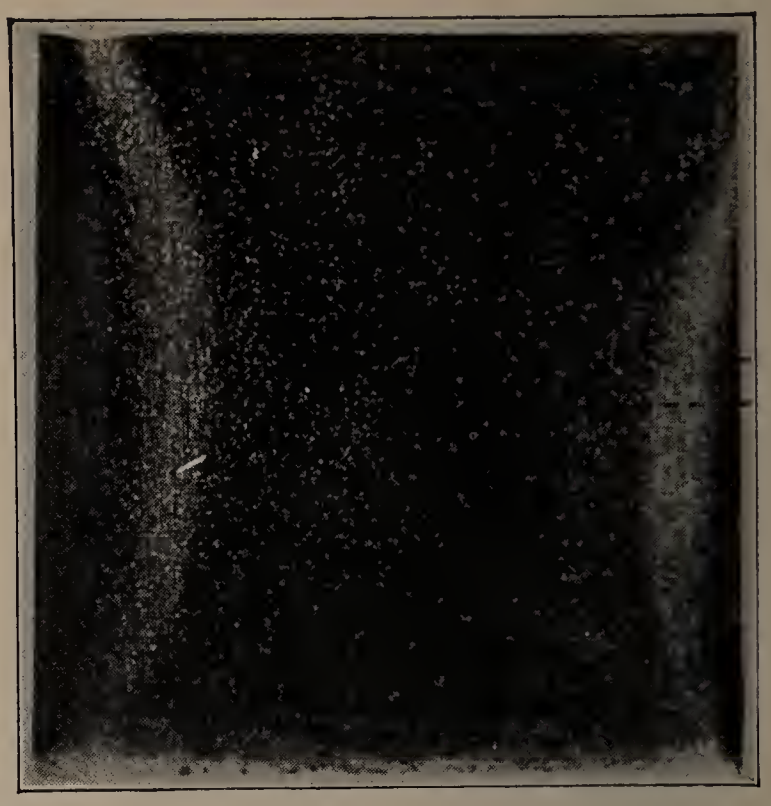


Fig. 8.—Change in Structure Due to Preheating with Flame.

this material, and these were not removed, or the material may have been overheated or even burnt. Later, during its actual service, fatigue stresses and unsatisfactory physical structure may have been produced. On forging again, unless done under the

Fig. 9.—Effect of Annealing Piece Shown in Fig. 8.

best conditions, further stresses will be set up and then, without annealing to refine the grain and remove these stresses, the forging will be returned to service again. While it may give some service, if we had gone a little further and treated it properly, the extended service would have been sufficiently great to more than recompense for any extra trouble or expense involved in a final annealing after forging. This same thought applies to welding of failed material or broken material which, through its previous service, has been subjected to severe

tensile strain or vibratory stresses. Later, the welder will do his work on the material and return it to service without attempting to anneal. It appears that there are a great many misconceptions in regard to the process of annealing and a great many shopmen fail to observe the rule that it requires time

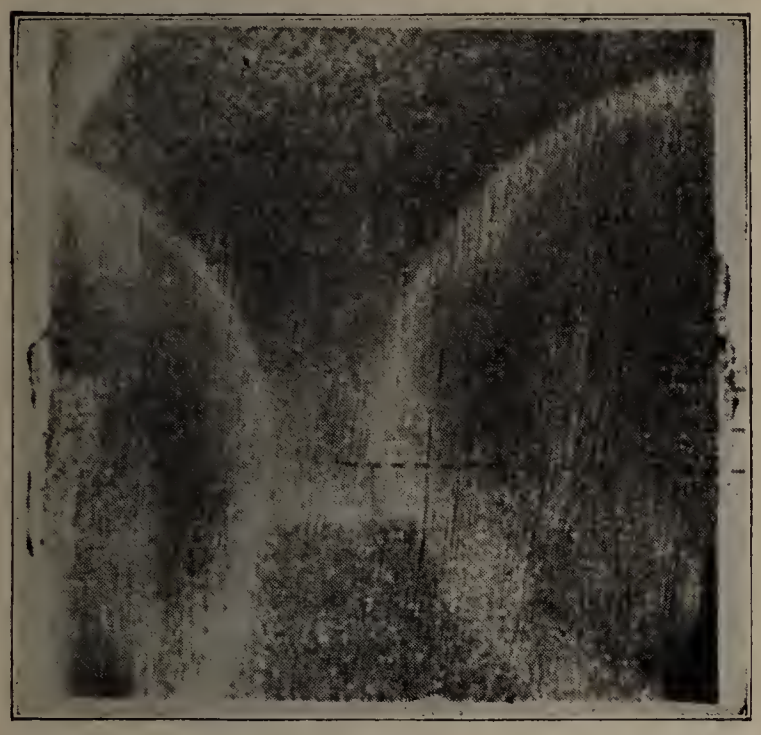


Fig. 10.—Ordinary Welding Practice.

for a piece of steel to adjust itself to the annealing temperature and be heated throughout to the same temperature. For

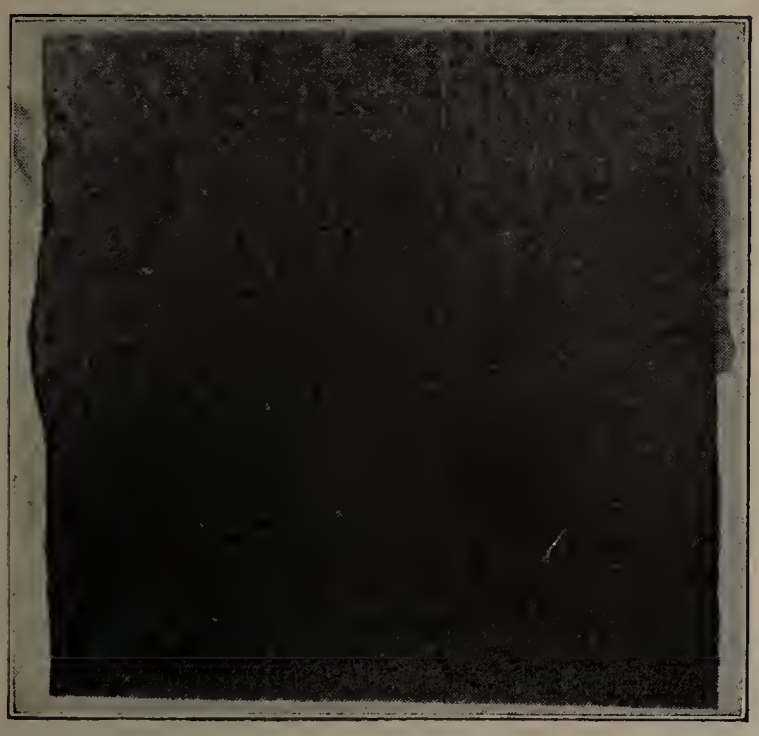


Fig. 11.—Annealing Has Removed Affected Zone.

instance, on one particular forging the party was instructed to thoroughly anneal the forging, and he advised that he was following this out. However, later it was found that he was simply sticking the forging into a blacksmith fire so that the welded area was buried in the fire. While the immediate area around the weld could be annealed in this way, at the same time it is a half-hearted way of going about the matter. Under such conditions, while the extreme highly localized affected areas will be removed, at the same time more or less minor stresses will be set up back along the forging and to do the job right the forging as a whole should have been subjected to the annealing heat.

The procedure involved in carrying out the various tests will be mentioned in connection with the different illustrations. The hardened area in question will, in a great

Fig. 12.—Metal Added Without Preheating.

majority of steels, correspond to the same hardness as if the steel had been heated and quenched, This method of bringing out this hardened area or the structural difference in the steel visible without magnification, is the same procedure that can be used in checking up the extent of the hardened or tempered area in various tools, such as chisels, hatchets, etc., and is comparatively a simple method. The surfaces are given a rough polish and dipped in nitric acid of specific gravity 1.13, or where this

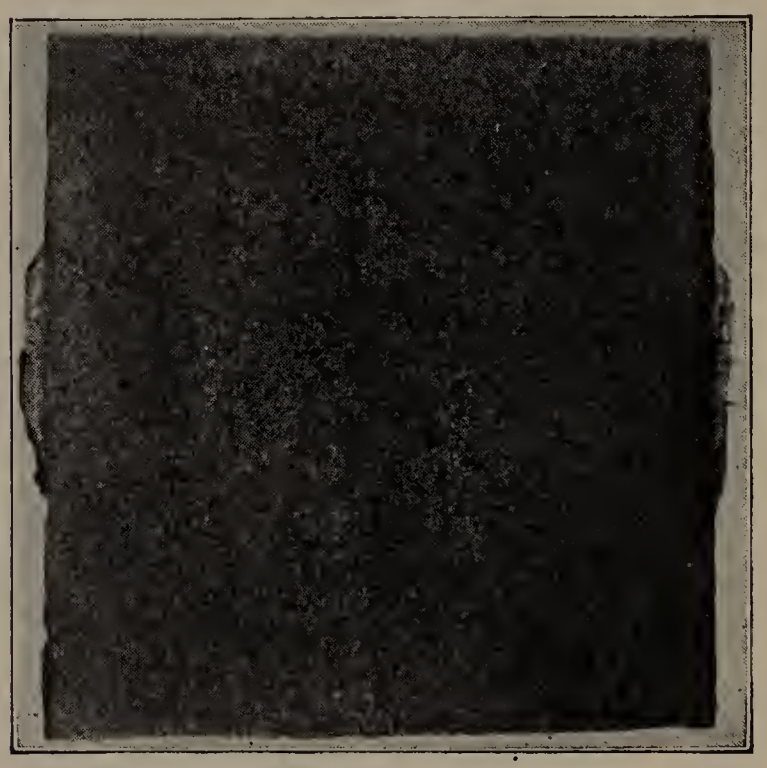


Fig. 13.—Same Piece Annealed.

is not practicable the acid can be poured over the steel.

In connection with the photographs illustrating the hardened area and zones affected by the heat, in making some of the tests, test strips were taken so as to embody only the extreme, hardened zones, and further test strips were taken progressing into the unaffected metal. It was found that in the zones where the hardened condition was

highly localized, these strips would not bend over 15 degrees before breaking or snapping off, but after annealing they could be bent flat on themselves the same as the original metal.

As an illustration of the application of the method of etching to develop hardened areas, the hatchet and chisel shown in Fig. 1 were first sand blasted and then dipped in nitric acid of specific gravity 1.13 for about a half a minute. Before this dipping the metal showed a uniform color over the whole surface, and after dipping it had the shaded appearance, as illustrated.

The maximum scleroscope hardness in the chisel in the darkened area at the cutting edge was 95, and this decreased to 55 in the body of the chisel.

In the case of the hatchet, the maximum hardness in the hardened area was 93 and decreased to an average hardness of 30 in the softest area of the hatchet.

A failed piston rod on which the cross head fit had been built up by the electric welding process is shown in Fig. 2. The photograph shows the added metal on the outer area around the circumference, and

Fig. 14.—Metal Added, No Preheating, and Then Annealed.

between this and the interior metal in the rod is an area scallop-shaped, affected by the welding heat. This represents the condition of the metal in the rod at the time of the failure.

The average scleroscope hardness of the added metal was 49, of the heat affected area 80, and of the metal in the rod proper 50.

The face of the saw cut opposite to Fig. 2 was taken and cut in two, both pieces being annealed, one-half being allowed to cool in the furnace and the other half in the air. It will be noted in Fig. 3 that the hardened area between the added metal and the parent metal has been eliminated.

The scleroscope hardness of the added metal in the upper piece, cooled in the furnace, was 38 and of the metal in the rod 55. The scleroscope hardness of the added metal in the piece cooled in the air was 38, and of the metal in the rod 57.

While the added metal in these two photos is shown in a black, shaded area, it should not be confused with the darkened area on the previous one, as in the latter two cases this was a matter of etching in order to show the differentiation between the added metal and the metal in the rod proper.

Fig. 4 is a piece of crank pin steel to which the patch was made after preheating the parent metal with the arc, resulting in the hardness numbers of 35 in the added metal, 50 in the hardened zone, and 47 in the rod. Metal added with electric arc.

After annealing, the hardened zones were removed, as shown in Fig. 5, and the hardness number in the added metal was 35, and in the rod 45. Metal added with electric arc.

The piece of pin shown in Fig. 6 was preheated in the blacksmith furnace and metal added by the electric process, resulting in the hardened zone as shown. The hardness number in the added metal was 34, in the hardened zone 59, and in the body of the pin 46.

After annealing, as in the previous instances, the hardened area was eliminated, as shown in Fig. 7, resulting in a hardness number in the added metal of 34 and in the rod 45. Metal added by electric arc.

Fig. 8 is piston rod which was preheated with oxy-acetylene torch, no metal being added, resulting in the heat affected area as shown by the shaded zones with a maximum hardness of the affected zones of 53, whereas the normal hardness in the rod was 44.

After annealing, the piston rod previously preheated with oxy-acetylene torch, no metal added, showed a normal hardness of 45 throughout the rod section (Fig. 9).

In the case shown in Fig. 10 the piston rod was preheated as per the regular practice and metal added with oxy-acetylene process, resulting in the affected zones, due to the preheating and welding heat, the hardness of the added metal in this case being 32 and the affected zones 53, the rod proper being 44.

Fig. 11 shows that on annealing the rod which had been preheated as per standard practice, metal added with acetylene flame, the affected zones were removed, and the added metal showed a hardness of 34 and the rod 44.

Fig. 12 shows the same affected zones on adding metal by the oxy-acetylene process, no preheating being done, the added metal showing a hardness of 32, the affected zones 53, and in the body of the rod 42.

On annealing the rod to which metal had been added by oxy-acetylene process, without any preheating, the affected areas were eliminated (Fig. 13), resulting in a hardness number in the added metal of 35 and in the rod 45.

Fig. 14 is simply a further illustration of where metal is added by the oxy-acetylene process, no preheating, and afterwards annealed.

Annealing, Electric

Annealing can be accomplished, in the case of small pieces, by placing them between the terminals of an electric resistance welding machine and turning on the current in the usual manner. Sufficient heat will quickly be generated to soften the metal.

Anode

The positive electrode of an electrolytic oxygen-hydrogen generator on which the oxygen gas collects. See "Generator."

"Anti-Borax"

Trade name for fluxes for use in welding cast iron, brass, bronze, malleable iron, steel cast and sheet aluminum. Made by Anti-Borax Compound Co., Fort Wayne, Ind. See Table of Contents, Catalog Section.

Antiron

An acid resisting iron. For properities and method of welding see "Dur-Iron".

"Apex"

Trade name for welding rods and wire. Made by Apex Steel Corporation, New York.

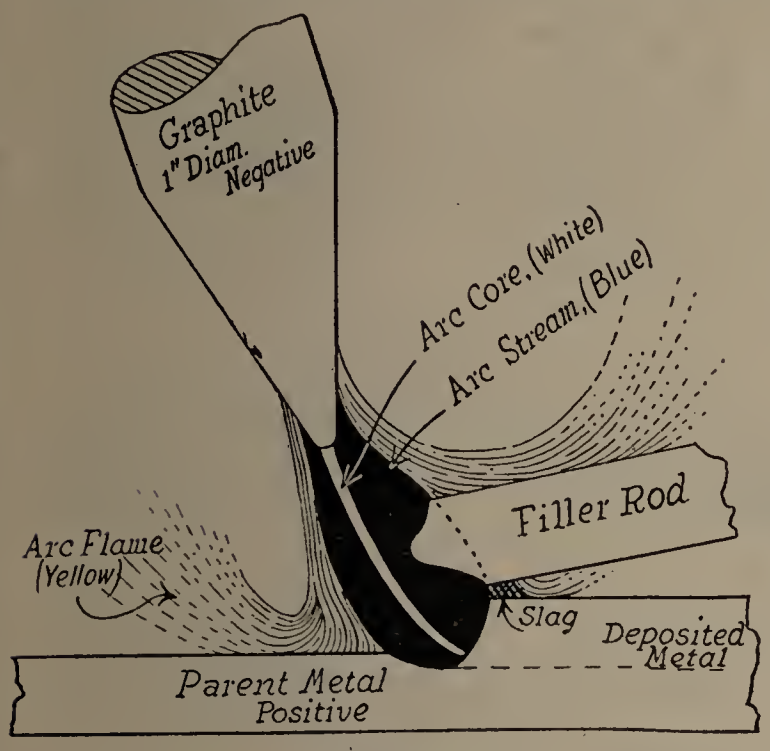
"Apex"

Trade name for special type of metallic arc welded rail joint. Made by Indianapolis Switch and Frog Co., Springfield, Ohio.

Arc

The successful effort of an electric current to jump across an air gap or other gas gap introduced in its circuit. There is considerable resistance introduced to the flow of the current, and it is this power massed at the point of the arc which brings the arc to such a high temperature and

makes it so useful for welding. In electric arc welding the arc is struck between a carbon or metallic electrode connected to one terminal of an electric generator and the metal to be welded, which is connected to the other terminal. The size of the arc can be varied by increasing the distance across the gap, by increasing or decreasing.



Details of the Electric Arc.

the amount of current (amperage) or by placing a varying resistance in the circuit.

"Arc Carbox"

Trade name for electric welding wire slightly high in carbon. Made by Central Steel and Wire Co., 127 N. Peoria St., Chicago. See Table of Contents, "Catalog Section."

Arc Core

A thin streak of white light from the tip of the graphite electrode to the work being welded by the electric arc process, marking the path of the current.

Arc Flame

A yellow flame outside the arc stream in electric arc welding.

Arc Stream

Stream of bluish light around the arc core in electric arc welding. The filler rod should penetrate the stream and just miss touching the arc core.

"Arcweld"

Trade name for rail bonds. Made by American Steel and Wire Co., 208 S. La Salle St., Chicago, Ill.

Arc Welding

Arc welding is the concentration of the heat in an electric circuit at an air or gas gap for the purpose of raising metals to be joined to a melting temperature. See chapter on "Electric Arc Welding."

Arc Welding Machine

A source of electrical energy with some means, generally automatic, of limiting the welding current within reasonable values.

"Arkweld"

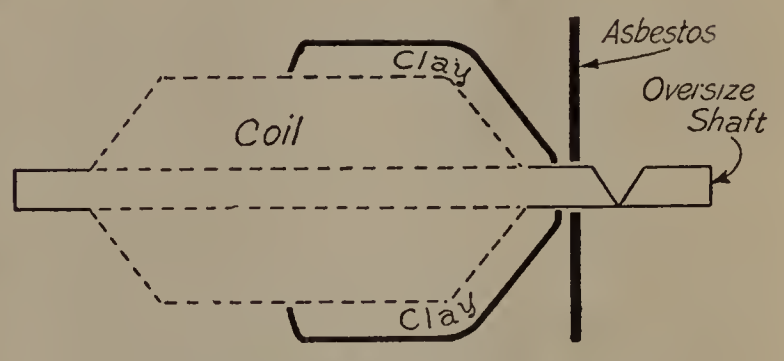
Trade name for protective helmet used in arc welding. Made by Julius King Optical Co., New York.

"Armco"

Trade name for iron welding rods and wire. Made by Page Steel & Wire Co., Bridgeport, Conn. See Table of Contents, Catalog Section.

Armature Shafts

When welding armature shafts the important consideration is to keep the heat away from the coils during the welding operation. This may be accomplished by packing them in wet clay making the clay packing heavy at the end of the shaft, where the break occurs. A large piece of asbestos paper may be used as a shield, cutting a hole in the center of it just the size of the shaft and sliding it over the end right up to the clay.



Protecting the Armature.

A. S. M. E.

American Society of Mechanical Engineers. The Boiler Code Committee of this society has in turn a sub-committee, whose findings and decisions are incorporated into the A. S. M. E., Boiler Code. This code has quite generally been adopted by states, cities, insurance companies. See section on "Rules and Regulations".

Asbestos

A fibrous mineral that has the property of withstanding high temperatures. It has a low thermal conductivity and is highly resistant to the action of acids. It is used as a heat insulator and to some extent as an electric insulator. Asbestos paper is practically indispensable in the welding

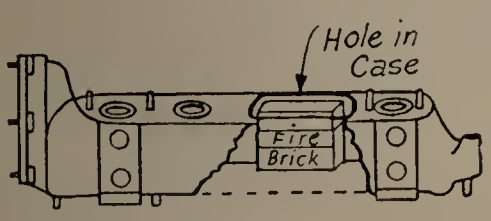


Fig. 1

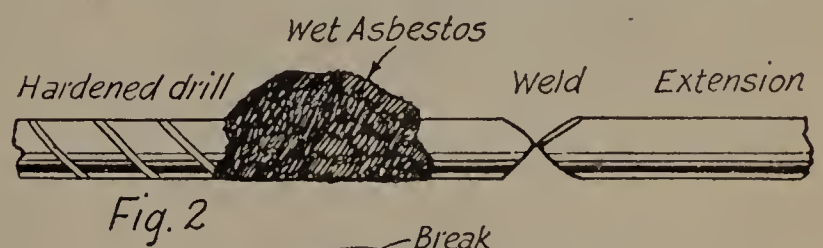
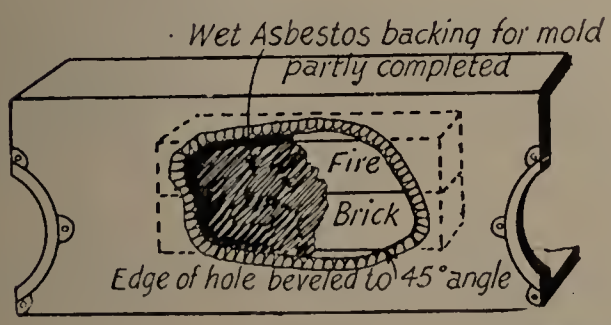


Fig. 2



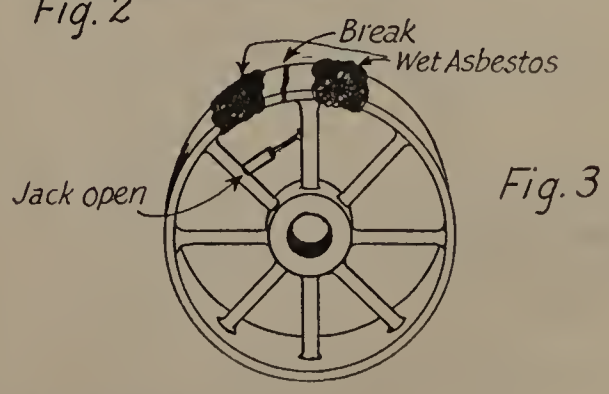


Fig. 3

Uses for Wet Asbestos.

shop, where it is used to cover welded parts so they will cool slowly and to partly cover parts being welded so the heat will not radiate so rapidly as to make the operator uncomfortable. Asbestos is also made into gloves and other protective clothing for men working near intense heat or handling hot metals.

To be fit for welding, asbestos paper must be a strong fabric and absolutely free from impurities, such as asphaltum, which give off noxious and injurious smoke, gases and fumes. If this paper is ground and mixed with water into an "asbestos paste" the welder will find hundreds of uses for it, a few of which are illustrated here. Fig. 1 shows a wet asbestos backing for a mold for a missing piece of an aluminum crank case, the mold to be made with plaster of paris. In this way a casting can be made the exact shape and thickness of the missing part, and welded into place. In Fig. 2 wet asbestos is being used as a protection for the hardened surface of a twist drill while welding on an extension. An emergency "repair in place" of a pulley wheel is illustrated in Fig. 3. Contraction effects are counteracted by expanding with a jack, and the wet asbestos localizes the heat effect. Such a repair will usually hold until the wheel can be taken down for a permanent job. When welding a nipple on a tank, a ring of wet asbestos placed as in Fig. 4 will serve to localize the heat and prevent buckling or warping. A seam welding job on light sheet metal is shown in Fig. 5. Here distortion is prevented by clamping on angle irons filled with wet asbestos parallel to the seam and as close to it as possible on each side. Another useful application is the protection of woodwork and painted surfaces when making repairs in place on automobile frames. The method of application is shown in Fig. 6.

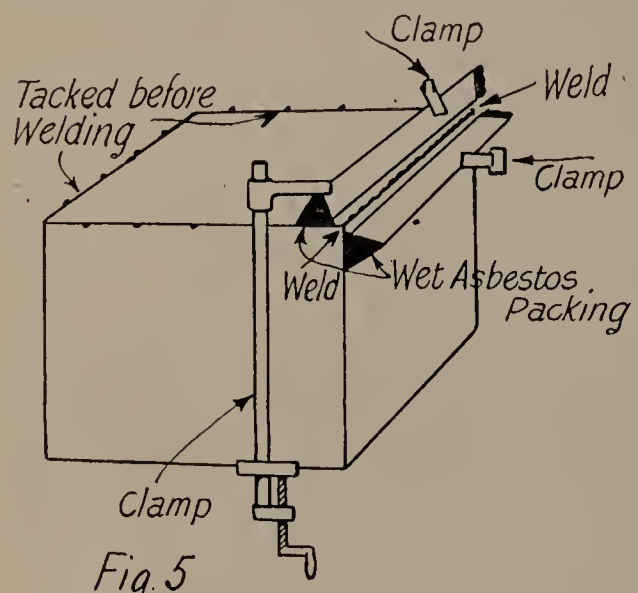


Fig. 5

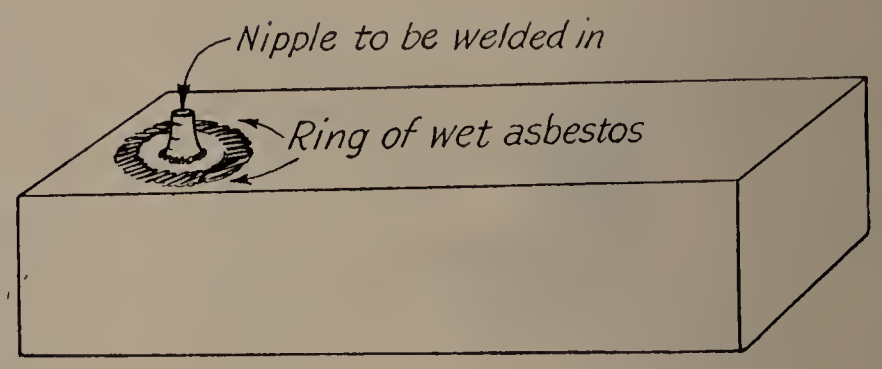


Fig. 4

Controlling Contraction with Asbestos.

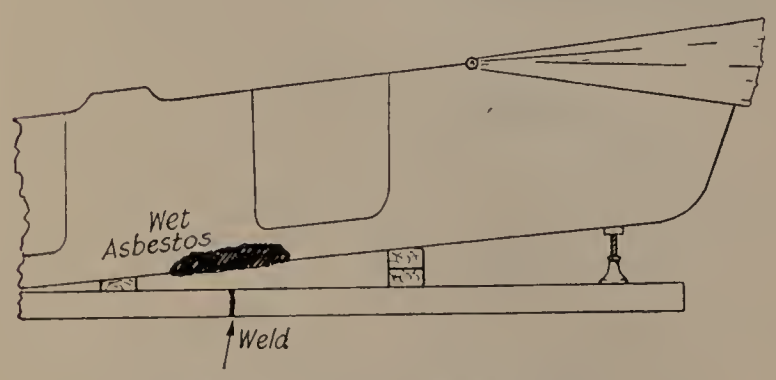


Fig. 6—Protecting the Work.

Many welders use a piece of asbestos paper for a shield, as shown in Fig. 7, when welding on heavy jobs, since the heat is often so intense that the working glove ordinarily worn does not protect the hand sufficiently.

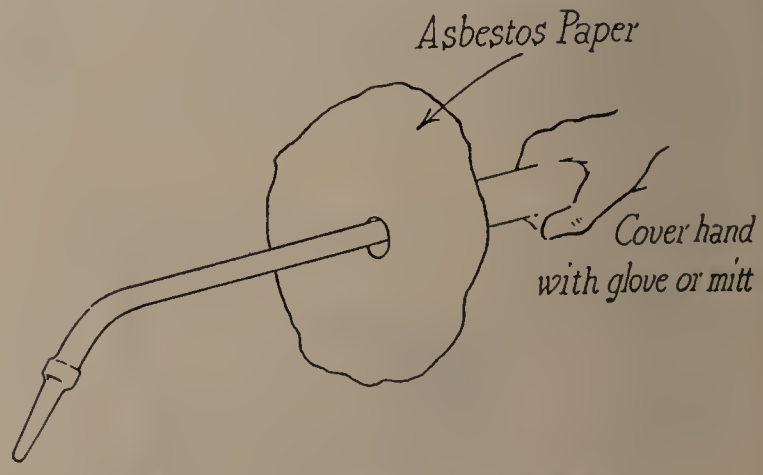


Fig. 7—Protecting the Operator.

Associations (Welding)

American Welding Society

An organization interested in welding by all methods. The parent society has headquarters at 33 W. 39th St., New York.

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A joint advisory board of the American Welding Society and of the National Research Council on welding research and standardization. The advisory board consists of representatives appointed by the American Welding Society, other interested scientific and engineering societies and organizations, classification societies, government bureaus and certain members who were appointed because of their special ability in matters pertaining to welding research and standardization. The officers are: Prof. C. A. Adams, Director; Mr. H. M. Hobart, First Vice-Director; Prof. A. S. Kinsey, Second Vice-Director, and Mr. Wm. Spraragen, Secretary. Office of the bureau is at 33 W. 39th St., New York.

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An organization developed to work in conjunction with the American Welding Society, and to furnish them with commercial data and information pertaining to Electric Arc Welding. The Acting Chairman of the Council is E. Wanamaker, Electrical Engineer, Rock Island Lines, LaSalle Street Station, Chicago.

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A joint committee of the American Welding Society and the American Railway Electrical Engineers' Association formed for the purpose of carrying on research in connection with the welding of rail joints on electric railways. The Secretary of the Committee is Wm. Spraragen, 33 W. 39th St., New York.

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An organization composed of manufacturers of oxygen and hydrogen. The secretary-treasurer of the association is C. T. Price, 140 N. Dearborn St., Chicago. A list of members of the association will be found in the Catalog Section.

Compressed Gas Association

An organization composed of makers and users of compressed gases. Headquarters at 23 E. 26th, New York, N. Y. The secretary of the association is John H. Hayes.

International Acetylene Association

An organization composed of manufacturers and users of acetylene, oxygen, hydrogen, welding and cutting torches, carbide and welding accessories and supplies, and also acetylene lighting equipment. This organization is the oldest society in the United States interested in welding and cutting. Splendid work has and is being done by the association in connection with legislative matters. Headquarters at Carbide and Carbon Bldg., New York, N. Y.

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"Atlas"

Trade name for cast iron welding rods, welding goggles and gauntlet gloves. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

Atmosphere

Unit used in measuring the pressure of gases. One atmosphere is a pressure of about fifteen pounds per square inch.

Autogenous

(A-toj' e-nus) Meaning self created or generated. Explained in many Encyclope-

dias under the term "Autogeneal", which is said to mean "I produce or generate." Autogenously, meaning spontaneously. It is plain that the word was first used to distinguish the present day advanced methods of welding from the older processes because it signifies the union of two sections of metal without the addition of some unlike metal as is not true of Brazing, for instance. See Fusion and Fusing.

Automatic Butt Weld

See under "Butt Welding" in chapter on "Electric Resistance Welding."

Automatic Spot Weld

See under "Spot Welding" in chapter on "Electric Resistance Welding."

Automobile Welding*

It has been most truthfully stated "the job welder is a jack of all trades." But contrary to the old saying, he must be "master of all." In the automobile repair shop, the welder's qualifications are necessarily of a wide variety. Primarily, he must be an expert with the welding torch: there are no half-way measures about welding in the automobile shop. His other requisites include metal working, blacksmithing, tinning, etc.

Constant vibration and innumerable shocks to which the automobile is at all times subjected cause numerous failures in the frame, running gear, or power plant. The parts, so affected, vary as to composition and size. They may be of cast-iron, aluminum, malleable iron, or any one of the many alloyed steels or forgings which enter into the assembly of the car.

Long usage attended by abnormal abuse and very infrequent attention—especially failure to lubricate properly—results in wear and tear of important parts. Others become so firmly rusted into place that even the sledge-hammer and heavy drifts are of no avail in their removal.

It is the lot of the welder to contend with all these difficulties, and it is expected that he rectify them all, whether it be the repair of a bent or fractured chassis, the removal of a bushing which has resisted the mechanic's efforts, the cutting out of rivets which cannot be reached with a chisel, and many others.

Once a welder begins to operate in the auto repair shop, the question invariably arises, "how did we ever get along without welding?' Undoubtedly the welding outfit must be classed as one of the very useful adjuncts in such a place. As a tool it serves so many purposes that it ranks above all other pieces of apparatus.

True enough, many shops operate without such an outfit. But they are handicapped greatly by the expense attached to sending out work, not forgetting the delay occasioned by such procedure. Furthermore, there are many occasions when it becomes impossible to send to the job welding shop for aid, although the use of the welding torch would reduce labor costs. Other methods must be resorted to, usually resulting in the pyramiding of expenses and long delays.

It is assumed, naturally, that the operator has the qualifications previously mentioned. Familiarity with his apparatus, a knowledge of materials, ability to execute successful welds are prime requisites. Members of the "plasterer's union" and "1918 models" are generally classed as unsuitable for this type of work and should be barred from participation in automobile activities as much as from any other branch of welding outside of sheet metal or small production work.

A really capable man can save the first cost of the apparatus within an incredibly short period and realize a neat profit for the proprietor at all times thereafter. Also, being an auto mechanic, he can find enough time between welding jobs to perform ordinary repair work, so that, at no time can he be classed as a "burden."

The work which falls to the welder in a repair shop may be classified under several general headings, as follows:

1—Heating—for forging, expanding parts, straightening, riveting, annealing, etc.

2—Welding—fractured parts and building up worn members.

3—Brazing—Fractured parts and building up worn members.

4—Miscellaneous: decarbonizing repairing scored cylinders, soldering, tinning, and miscellaneous cutting such as plate work, rivets, etc.

Although local heat may be applied by the use of several methods—forge, fuel oil preheater, blowtorch, or charcoal fire—there is no simpler means, nor one so convenient as the oxy-acetylene torch. At first hand its use may appear to entail a higher cost. Actually this is not true when balanced against the labor saved through its rapid action. The high temperature of the oxy-acetylene flame rapidly transmits its heat to the part to be worked so that the high charge which is usually allowed for a mechanic's time is minimized.†

Bent chassis frames, steering knuckles, axles, shafts, etc. are examples of parts which can be readily repaired by heating with the torch and then straightening. Holes are easily drifted through spring leaves after heat has been applied in this fashion.

Formerly the idea was prevalent that only in a blacksmith's forge could an axle be handled properly. This impression has been discounted as a fallacy. Axles of the heaviest I-beam types can be handled successfully and very efficiently in the auto repair shop. Of course means must be at hand for proper alignment, but outside of this one requirement no special tools are needed. Two heavy wooden beams, a heavy sledge-hammer, the torch, and a straightedge generally comprise the entire equipment, although a surface table would be an advisable addition.

For the straightening of heavy axles, the tip of maximum gas capacity is probably the most efficient for quickly heating the affected section. The volume of material in I-beam axles is generally large, and so distributed, that a large surface is provided for heat radiation. Protecting these surfaces with sheet asbestos to reflect the leak back to the axle is an economical procedure.

When riveting brackets to the frame or on similar work, the welding torch is a suitable source of heat supply, especially when the shop is not equipped with a forge, or even if so equipped, the forge is not operating at the time. On the other hand, the removal of rivets is facilitated by cutting off the heads, so that the shank of the rivet can be drifted out with a hammer. A special bent nozzle for the cutting torch can be obtained from apparatus manufacturers for this purpose. Sometimes a bracket has cracked but is still held loosely in place by the rivets. The addition of filler rod, or if a malleable casting is so loosened, the addition of tobin bronze rod suffices to remedy this faulty condition.

Hardly a day passes without there being at least four or five calls for some way of producing expansion. Either a stud is to be removed, or a bushing cannot be forced into place, or possibly a flange must be expanded so that it can be assembled and allowed to shrink to a force fit. It is remarkable how much manual labor can be eliminated by so simple an operation as the application of localized heat. Where mighty

**Written for The Welding Engineer by B. Heyman.*

hammer blows would ordinarily fail to produce movement in assembling parts, expansion of the proper member permits very easy fitting together, with a certainty that upon cooling the part enclosed is held firmly.†

Welding automobile parts calls for wide experience on the part of the welder. He must know metals. He must be an adept at producing results. Very often he must execute welds without the proper means for aligning or preparing the fracture, while at other times he must work in seemingly inaccessible places. His work is varied. One day he may have nothing but steel; another may bring only aluminum. Each and every job has its peculiar requirements. He must contend with steels which are generally alloyed and prepared by special heat treatments, requiring the use of proper filling rods and extreme care in handling under the intense heat of the torch flame.

Seasonal work is very noticeable in the auto shop. It is to be expected that cracked water jackets will be numerous during the winter. Although the welding operation is in itself very simple, the handling of an automobile cylinder block during the preheating and annealing stages is a difficult matter. The cylinders are easily warped, or undue strains may be set up to result in fractures at a later time.

The power plant, running gear, and frame all yield work to the welder. Examples are so numerous that only a few need be mentioned: crank-cases, chassis, shafts, flanges, housing, brackets, rods, etc. There is hardly a part which cannot be reclaimed at a small actual cost compared to the cost of a duplicate where the latter can be procured. In the case of old and obsolete models, stock parts have become very scarce.

Malleable iron enters into the composition of the majority of automobile castings, especially those of small size. These must of necessity be brazed when fractured. However, it is not unusual for the welder to use steel filler rod, when the casting is very thin, with successful results. On some of the worn castings, it is also much simpler and cheaper to add a bronze filler and then finish by filing, rather than to weld with steel. This is especially true in parts where under normal operating conditions there is no wearing action, but, due to the loosening of a bolt or nut, movement has occurred and the friction has finally had its effect.

Under miscellaneous work has been noted several operations which really pertain to the welder. Familiarity with apparatus, and the fact that he appreciates better than the average auto mechanic the dangers arising from improper use of oxy-acetylene equipments, points him out as the logical person to handle the decarbonizing of automobile cylinders.

The filling of scores in cylinders is another type of work which the welder can perform advantageously, in that it requires considerable dexterity. There are many low-temperature preparations on the market for repairing such defects. Or if so requested by the customer the scores can be welded and the cylinders rebored.

It is not unusual, after a welder has been in such a shop for a short time, to have almost any difficult job thrown at him. To the other mechanics he seems to be a superman. He is expected to do the impossible. If, for example, a mechanic fractures a lug or bracket while assembling some member of the car, which may mean disassembling ordinarily, the welder is asked, "can't you stick it on someway, so it will hold?" Or a weld may be required close to the gasoline tank, and the mechanic will wonder why the welder refuses to undertake the work until the gasoline tank has been removed. He could probably understand more readily if he once saw the results.

Several precautionary measures should be taken in performing welding work in the auto repair shop. A chemical fire extinguisher and sand should be placed in a convenient place, easily accessible. No matter how careful the welder may be, there is a possibility of danger attending the use of the torch in a place where gasoline vapor is always present. Sheet asbestos should be used to cover oil-soaked parts, to protect the gasoline supply line when working on the car and when these parts have not been removed.

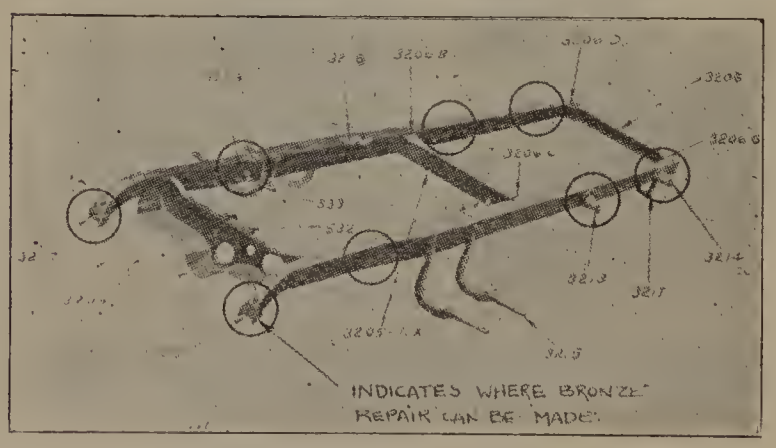
See also under "Motor Heads," "Carbon Burning," "Malleable Iron," "Radiator Repairs," "Chassis Welding," "Automobile Cylinders," "Crank Cases," "Cast Iron," "Fenders," "Bumpers," "Preheating," etc.

Automobile Welding With Bronze.

Bronze finds its greatest use in the repair of brass and bronze parts, malleable castings, or in the joining of articles, the size and thickness of which forbid the use of the extremely intense neutral flame for the length of time necessary to produce fusion and addition of filler rod. Also, in some few particular instances, bronze is used on castings where it is deemed advisable to eliminate preheating, annealing which goes hand in hand with the addition of cast iron filler.

There is nothing unusual in the employment of brass or bronze in the welding of non-ferrous castings containing combinations of copper with zinc, or tin. It is customary practice in any shop where welding or brazing is performed. Failure to handle the rod and flame properly are the chief difficulties with which the welder must contend. Volatilization occurs rapidly, the zinc passing off in the form of a white fume which causes discomfort to the operator and leaves a welding section which may vary in chemical composition anywhere from pure copper to practically the original rod.

The nature of a malleable casting is such as to preclude welding, unless it be so thin



Bronze Repairs on Frames.

as to consist, almost through its entire section, of pure iron. In such a case the use of a steel filler offers a very satisfactory remedy. On the other hand, where only the skin of the casting has profited through treatment (this does not refer to the physical properties which are identical throughout the casting) use of cast iron or steel filler should be avoided. The attempt to use cast iron or steel is difficult and most generally results in a beautiful piece of "botching." The skin of the casting blows away and as the rod is puddled under the surface,

†*The use of the acetylene torch is economical only when a quick and highly localized heat is desired on a small area. For long jobs it is better to take the time to heat with an oil torch.*

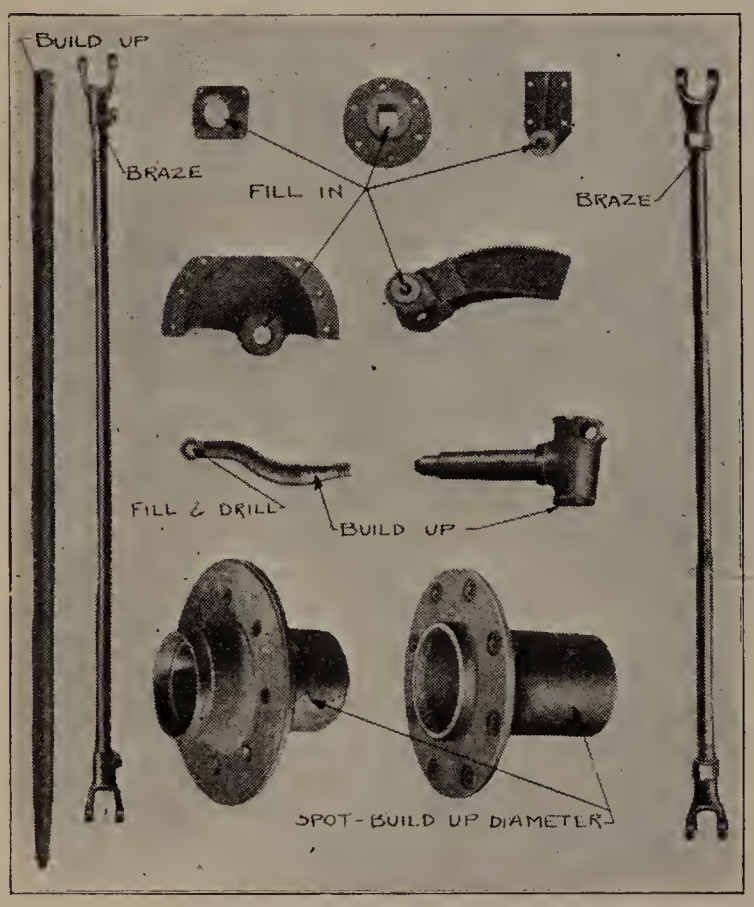
blowholes and pits are formed so rapidly and in such numbers that they cannot be eliminated. Proper fusion cannot be accomplished. Although the metal appears to be plastic it does not join readily with the rod, and the final result appears to be more nearly adhesion than it does fusion.

The use of bronze in conjunction with a suitable flux is the readiest means of repairing. Thus the casting should be brought to the proper temperature along the lines of fracture, and the bronze added under the action of a slightly carbonizing flame, to avoid oxidizing the volatile elements of the rod. Emphasis must be placed on the use of fluxing in sufficient quantities.

The reinforcement of all brazed joints is very important. In every case where a welding repair is consummated through the agency of bronze rods, and a permanent strength joint is expected, sufficient reinforcing is an absolute necessity.

Tensile tests of brazed malleable bars, have shown that in every case, fracture occurred at the juncture between the bronze and the malleable iron. Increasing the area of contact, whenever possible, increases the ultimate strength of the joint. From this it appears that a combination of large surface contact and heavy addition of the bronze would give the best results.

In building up the bronze rod at a joint never melt the bronze which has been applied unless more filler is deposited at the same time. Carelessness in heeding this, results in a spongy, copper colored metal which is very weak in structure. The usual procedure after the first application of bronze (applying a thin layer on the original casting) is to tip the torch so that the full effect of the same does not impinge upon the deposited metal.



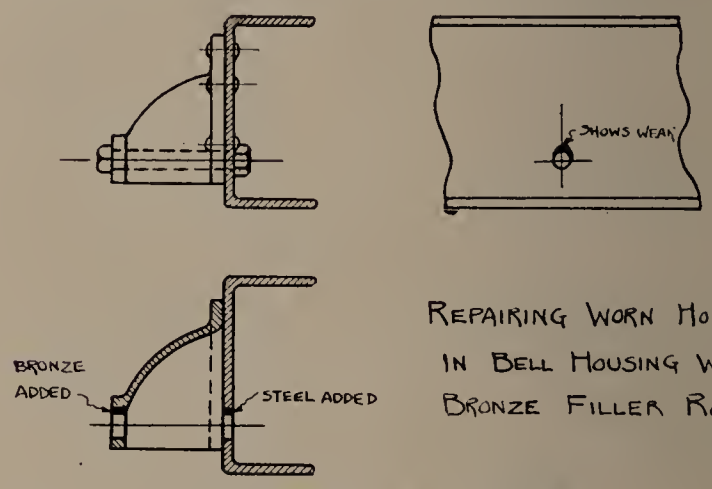
Odd Jobs with Bronze.

In the case of castings where ordinarily a gray iron filler should be used but it is preferred to eliminate the preheating and annealing processes which are so necessary to prevent strains, bronze filler can be used very advantageously. The casting must be prepared by beveling the edges of the fracture and then drilling and tapping these edges for studs in similar fashion to the methods employed for arc welding cast iron. The bronze is then deposited upon the casting in the manner described at tinning. A thin sheet is applied and upon this are deposited the final layers which of necessity are wrapped around the studs.

There are many applications where strength is not an essential or disturbing factor. The ease of manipulating the bronze rod makes it a particularly useful instrument in the hands of an experienced torch operator. Light sheet metal parts, such as tubes for exhaust pipes, fender parts, in fact any light pressed steel parts can be repaired by joining the edges with bronze. The operation requires only a very short time to complete and no unusual dexterity on the part of the operator, outside of his taking proper precautions to prevent buckling or warping of adjoining sections. By packing wet asbestos at the adjoining sections, expansion can be held to very narrow limits and the resultant effect practically nullified.

Parts which under normal conditions either exert no wearing action or are not actually considered as bearings, but have become worn because of excessive abuse and lack of lubrication can be quickly reclaimed by the use of bronze. Not only is this material perfectly satisfactory from the standpoint of service requirements, but it is also very cheaply applied.

In automobile work, for example, let us consider the bell housings and goosenecks



Bronze Repair of Housing.

of the average automobile truck. Although the shackle bolts which pass through these are not supposed to have any wearing action on the castings, and are supposed to be lubricated thoroughly, the heavy jolts to which the automobile is constantly subjected, causing motion of the springs, transmits a slight movement to the hardened steel shackle bolts. In time the castings become worn at the top of the opening, leaving sufficient clearance for the bolts to move in a vertical direction. Now in the tubes within the differential housing by brazing the heads of the rivets to the housing and also running a heavy band of bronze around the joint between the tube and housing a permanent repair can be effected. The parts, however, must be thoroughly cleaned with gasoline before brazing is begun, in order to remove all traces of oil and grease from the surfaces. These should also be filed clean, and thoroughly fluxed after the flame has been applied.

Steering arm levers and other parts which contain bushings are generally a source of annoyance due to the bushings wearing rapidly. Where a bushing can be obtained, replacement is advisable. At times, however, this becomes impossible, as when stock parts are depleted and there is no time to machine the bushings from bar stock. It is very simple to fill the opening with bronze, and drill and ream to size.

Tie rod clevises easily jar loose, and, due to the play of the casting on the threaded ends of the bar while the truck is being steered, wear so badly that the threads are

entirely destroyed, making the castings and bar worthless. It is very inexpensive to braze the castings to the rod, after the wheels have been aligned, the entire operation requiring only a few moments and very little material or gases.

Occasionally shafts are discovered to have worn under the race of a bearing where under normal conditions the race should be a force fit. The addition of bronze around the shaft reclaims it and makes it as serviceable as a new one.

Universal flanges for drive shafts are generally made with a square opening which fits tight on the pinion shaft of the differential. The shock due to transmitting power to the rear wheels wear the square opening until it rattles freely and is a source of annoyance and loss of power. Addition of bronze where worn until the opening is about the size of the shaft and forcing the flange on while red hot produces a shrink fit which when cold is even better than the original fit.

Wheel hubs which in the course of repair work must be transferred from one wheel to another are sometimes found to be undersize. Spotting the entire circumference with bronze is a means for increasing the diameter so that the hub becomes a press fit in the wooden felloe.

These are only a few of the numerous applications to automobile parts, frequently some other part of the automobile is damaged as a result of this condition, the shocks being transmitted in part to the frame and power plant, instead of being absorbed entirely by the springs. Some of the wearing action also takes place where the bolt passes through the frame. Unless checked in time fracture is almost certain.

In order to repair this faulty condition the shackle bolts must be removed and the spring dropped. This gives ready access to the worn members. The casting is brought to the temperature at which bronze can be deposited most readily. Flux must be applied freely in order to clean the surfaces thoroughly and to aid in the deposition of rod. An old shackle bolt is then slipped into position, leaving place for the rod and flame to enter the worn section and the bronze added to the casting. The action must be very rapid and the rod must be handled with extreme care to avoid volatilization. The shackle bolt is drifted out of the opening before cooling has progressed to any appreciable extent.

The same method may be used in repairing the worn opening in the chassis, excepting that a steel filler is substituted for the bronze rod. The steel must be fused rapidly without oxidation. Usually the rod is added across the lowest point of the opening so that a bridge of metal is formed. The bolt is then removed and addition of steel continued in an upward direction.

Very little filing is necessary after such a procedure. The slight contraction that takes place is just enough to permit a force fit for the bolts.

—B—

"B-B-B"

Trade name for welding and cutting torches and regulators. Made by Bishop-Babcock-Becker Co., Cleveland.

Babbit

A soft alloy of copper, tin and zinc, used in bearings to lessen friction. To heat bearings to pour babbit acetylene only or oxygen and acetylene, or other gas mixtures may be used.

Babbitted Bearings

Crank case repairs in some instances involve the repouring of babbitted bearings, since the babbitted metal melts at such a low temperature as to be lost when the weld is made in the vicinity of the bearings. Some shops manage to save these bearings by placing a piece of pipe in position in the bearings normally occupied by the shaft and keeping cold water flowing through the pipe throughout the operation. This serves to keep the bearing cool enough so that they will not be lost.

"Back It Up"

Trade name for fire resisting product for backing up welds, making moulds, etc., made by Big Three Welding & Equipment Co., Ft. Worth, Texas.

Backfire.

Sometimes used as a synonym for flashback. Engineers usually define it as a momentary return of the gases, not necessitating shutting off the gases as does a flashback. Indicated in the torch by a snap or pop, the flame immediately recovering itself and burning at the tip in the usual manner. See Flashback, Pre-ignition and Flame Propagation.

Back Step Welding

Term applied to electric arc welding when the operator first welds a series of tacks a few inches apart, welds the first interval, skips to the fourth, then to the seventh, and so on until the end of the seam is reached, then goes back to the second, fifth, eighth, and so on. By using this method the welding is always done in a comparatively cool area and the distortions caused by expansion and contraction are greatly reduced.

Backward Welding

Welding backwards may be defined as the method of executing a weld in which the welding rod follows the blowpipe as opposed to preceding it. Or again, it may be defined as a method in which the flame is inclined

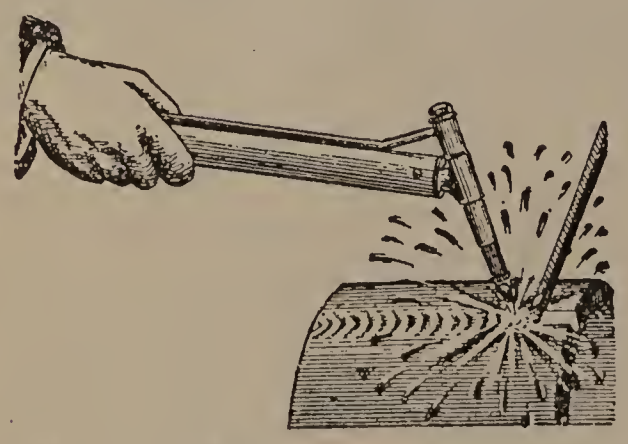


Fig. 1.—Usual Position of Blowpipe and Welding Rod.

towards the welded portion. A fuller and perhaps better definition would be: The flame is inclined backwards and only undergoes a slight transversal motion in addition to its regular advancement, the welding rod follows the flame and is given a movement, the end of the rod always being molten.

In conclusion it may be stated that welding backwards consists in operating in a manner almost exactly opposite to forward welding, if this latter expression can be used to designate the usual method of executing welds.

Advantages.—Having acquired the method of welding backwards the welder will find it easier to execute welds by this method. The penetration is always satisfactory, adhesion is almost impossible; the metal is sound, there is a diminution in the amount of oxide, and the metal is more ductile. Finally, the speed of welding is very much greater than with the old method, from which it will be gathered that there is economy in labor and gases which amounts to at least 25 per cent and sometimes reaches 30 to 35 per cent. The economy in the consumption of filling material is of the same order as it is possible to reduce the beveling angle. To summarize, we have better welds, with a guarantee of good execution, and great economy.

Applications.—This method of welding is applied mainly to steel plate above ⅛ inch in thickness. It should be used on all plates falling in the range of ⅛ to ½ inch in thickness.

The process is particularly valuable for certain industries such as the manufacture of boilers, etc.

Its application to mild steel has been specially studied. A certain number of experiments which have been made have shown that welding backwards gives better results than the usual method when welding steels with a higher carbon content—medium and hard. It is not satisfactory for aluminum welding and gives indifferent results when welding cast iron. On the other hand, the first series of tests in using the method when welding copper and brasses have proved satisfactory.

When comparing the backward method of executing welds with other methods, one might say that welding backwards is a "more mechanical" method. From this it follows that more definite rules have to be observed in executing welds and it is advisable, especially for beginners, to strictly observe the rules laid down. These instructions, which are the result of investigation, may subsequently be modified and added to, but in the meantime they give good results and should be followed.

For example, it will be noticed that for this method of welding, the edges of the two pieces of metal to be welded should be chamfered or beveled, so that when they are placed together, the two beveled edges form a V. Although the angles of the bevel can be reduced, beveling is still indispensable, even on thin material.

Preparation of the Metal.—The parts to be welded are prepared in the ordinary way, tacks, or short welds, at intervals of from 2 to 6 inches, according to the thickness of material may be used. In the absence of jigs, the parts are supported so that the lower edges are in the same horizontal plane. The angle of the V formed by the two beveled plates should never exceed 90 degrees, and, as already mentioned, for this method can be distinctly less. Beginners can gradually reduce the angle of the V from the previous standard of 90 degrees until they arrive at 60 degrees for material ¼ inch in thickness or above, and for material between ⅛ inch and ¼ inch an angle of between 45 and 50 degrees can be used. (Figs. 4 and 5.)

The beveling should be carefully done and extend the full depth of the plates as partial beveling will produce defective welds.

Welding Rod.—The choice of the right size of welding rod or wire is of great importance. A wire that is too small melts too freely, has a tendency to burn, and is distributed badly. The defects of adhesion and

oxide inclusions are common. If the wire is too large, the rate of welding is retarded, the molten bath is cooled, and it is difficult to add the metal uniformly. In both cases burning and overheating of the welding rod and material are likely to take place.

The following table gives the sizes of wire for welding various thicknesses. It will be noticed that they are slightly less than the values previously given for the ordinary method of executing welds.

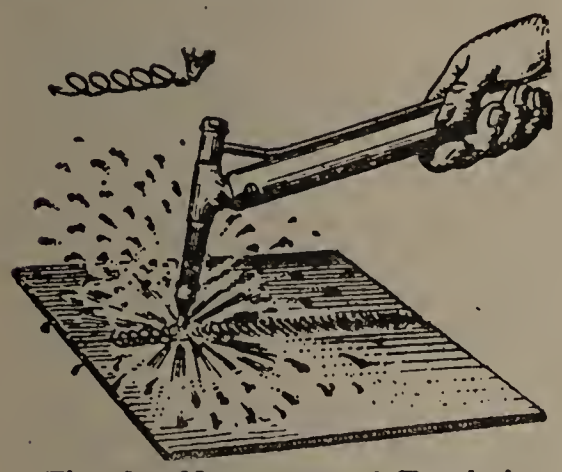


Fig. 2.—Movement of Torch in Continuous Weld.

Thickness To Be Welded In Inches	Diameter of Wire Decimal		
	S. W. G.	Equiv.	Nearest $\frac{1}{64}$
$\frac{1}{8}$	14	0.081	5
$\frac{5}{32}$ to $\frac{3}{16}$	11	0.116	8
$\frac{1}{4}$ to $\frac{9}{32}$	8	0.160	10
$\frac{11}{32}$ to $\frac{13}{32}$	6	0.192	12
Above	4	0.232	15

Position of Blowpipe.—The flame of the blowpipe should be given a definite inclination. In certain cases and especially with expert welders, familiar with this method of executing welds, this inclination of the flame to the plane of the weld is very small, in other words, the flame is almost perpendicular to the weld. A series of experiments have been made to discover the best angles and have shown that an angle of 20 degrees gives the results, that is to say, the angles between the nozzle of the blowpipe and the perpendicular should be 20 degrees, the flame being turned backwards as shown in Fig. 6. Beginners should pay particular attention to obtaining and practically working at this angle of inclination.

—*Marcel Piette, in the Revue de la Soudure Antogene.*

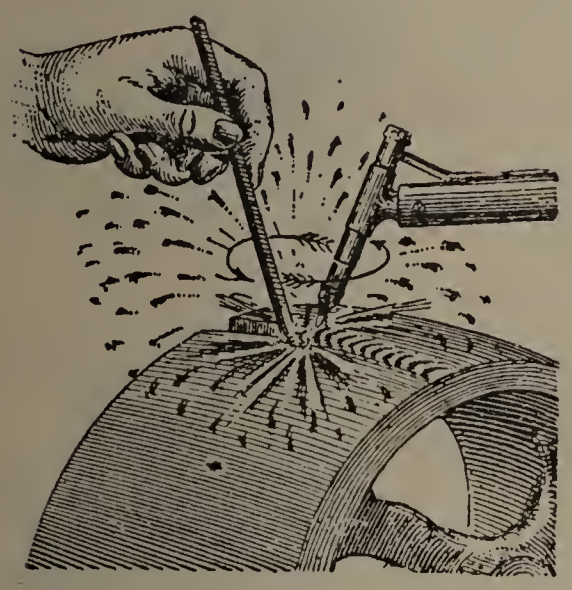


Fig. 3.—Manipulation of Torch in Welding Thick Material. Forward Style.

Balanced Pressure Principle

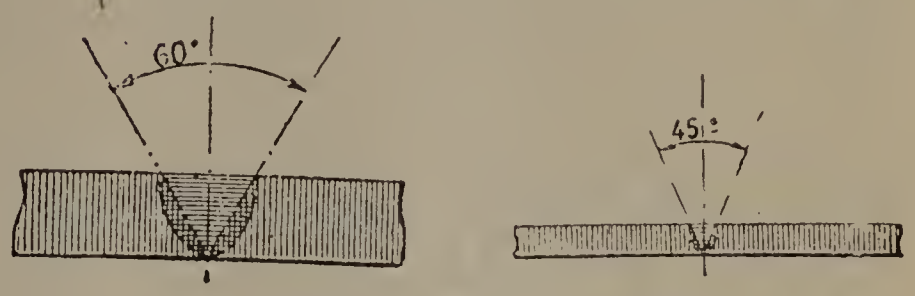
See "Torch Classification."

Band-Saws

Band-saws should be brazed, not welded. Use a silver solder and bevel the ends to be brazed to a good, sharp edge, the length of the bevel depending upon the width of the saw. It is perfectly feasible to pound a silver coin thin; apply it between the surfaces to be brazed or soldered, applying damp, powdered borax. Apply the heat of the torch carefully and as the silver melts clamp the beveled edges together. Let the joint cool gradually and grind or file off as needed.

Bare Wire Electrode

An electrode, for arc welding, that has no coating of flux, slag, or other artificial content.



Figs. 4 and 5.—Beveling for Thick and Thin Material

"Barthel"

Trade name for oil burners. Made by Aeroil Burner Co., Inc., Union Hill, N. J.

Base Metal

Material composing the pieces to be united by welding.

Bead

Metal deposited in oxy-acetylene or electric welding when the torch or electrode is carried in a single direction. Also refers to thin ridge of metal on the reverse side of an oxy-acetylene or electric arc butt-weld. The presence of the bead on the reverse side of the weld is an indication of thorough penetration, but not necessarily perfect fusion.

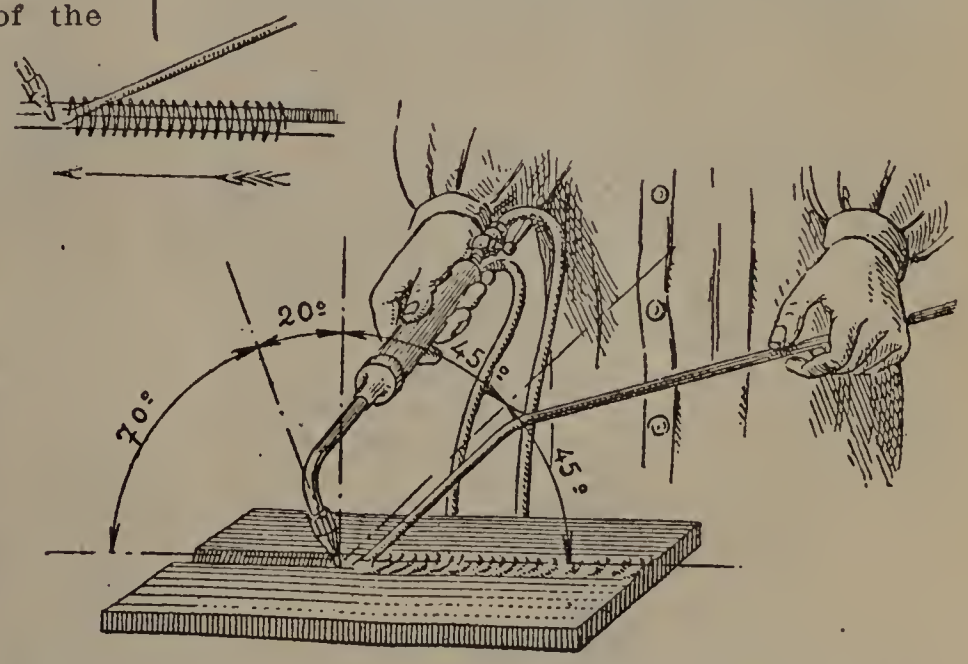


Fig. 6.—Position of Blowpipe and Welding Wire in Backward Welding.

Bead Forming

The simplest operation in depositing metal by the metallic arc process, and usually the first exercise for the beginner. While forming beads the operator requires the habit of making all of the electrode material flow into the crater produced by the arc. To make this bead successful, it is necessary to keep the arc just ahead of the metal which has been deposited, i. e. on the advancing edge of the crater. An examination of beads will show whether the operator is using the proper current and the proper arc length. An excess of heat will cause the arc to produce a larger crater than the deposit will

fill, leaving a small crevice along the edge of the bead. And holding too long an arc will cause the deposit to overlap on the parent metal excessively without securing the proper penetration.

Beading Weld

A weld made so that the metal is deposited by advancing in a single direction.

Bearing

The support or wearing surface for a revolving shaft.

"Befco"

Trade name for welding rods, wire, solder and fluxes. Made by Bierman Everett Foundry Co., Irvington, N. J.

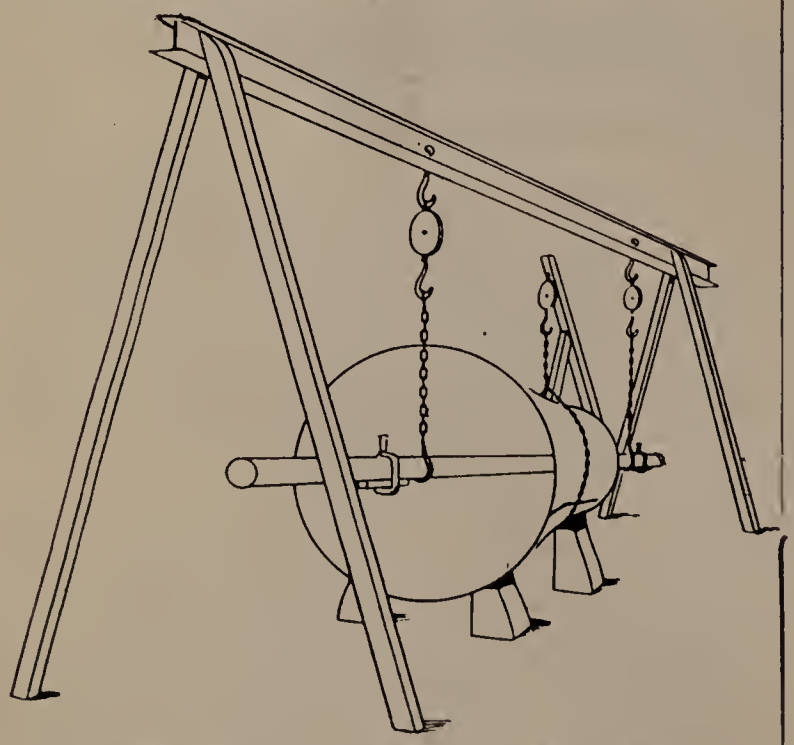
Bell

A receiver for storing gases. Usually consists of an inverted metal cup floating in

Bells

One case is recorded of the welding of a bronze bell fifty years old, without changing its tone. The bell is now in service and apparently as good as new. It is five feet from lip to lip and weighs sixteen hundred and fifty pounds. The sides are about four inches thick. The metal is a composition of copper and tin, chips like hard brass but welds like copper. It was impossible to remove the bell from its position without great cost so a furnace was built in the belfry for the purpose of preheating. Three hundred and fifty-five bricks were required for the furnace and fifteen bushels of charcoal for the fire. Preheating was necessary to avoid shrinkage crack in the bell when it cooled down at the weld. The oxy-acetylene torch was used to light the charcoal, and a moulder's hand-bellows for blowing. The bell was heated until it would melt solder. On application of the torch the metal flowed almost instantly. The crack occurred on the side next to the supporting frame. It was necessary to loosen the bell and turn and tip it until the crack was on a level. The entire crack was veed out and a piece of boiler steel clamped inside the bell, under the crack, to prevent the molten metal from dropping through. Three hours were required for welding, two cylinders of acetylene, three of oxygen and thirty-seven pounds of bronze filling rod being consumed. After the weld was completed it was polished with a small electric grinder.

Since one of the most troublesome questions in welding large bells is presented by their extremely awkward shape, the following description of the welding of a 2800-pound bell is given:



Holding the Bell Steady for Welding.

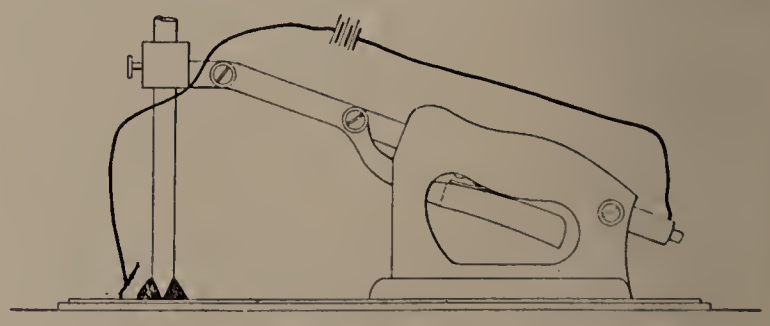
The length of the crack was 36 inches and the thickest part of the bell was 5 inches. First a basket of heavy screen was made to hold chareoal and the bell preheated for three hours. The welding was started before the bell was hot enough to melt lead, and the first part of the weld extended about 12 inches from the end of the crack. Then the bell was turned and the opposite side brought down 24 inches and turned again, and so on. The turning of the bell was done with a chain hoist. Three strands of chain were wrapped through the top and lower openings of the bell, then holding two strands and leaving the third one loose permitted the bell to slide down easily for a new hold. To hold the bell at the proper level where the welding was being done, a bar was put through both openings of the bell, to which another hoist was attached. Two leather dogs were clamped to the bar to prevent the chains from slipping. When welding the inside of the bell, the basket of charcoal was taken out and fresh coal added so that when welding was started again there was a good hot fire ready to set inside the bell again. During preheating the basket was covered with a large sheet iron having an opening so that charcoal could be added easily. when chipping out the crack as many chips as possible were saved and melted into the weld, especially on the surface, giving the bell its original color when finished. It was difficult to find the extreme end of the crack even with the help of a magnifying glass. Three holes were drilled to find it, but it was soon found that the end of the crack had not been reached, so a fourth hole was drilled part way through and coal oil poured in it, and this soon located the end. The filling material was manganese bronze filler rod and chips from the bell.

Bending Test

When weld has cooled place test piece in a vise in such a way that the line of the weld is just above the jaws of the vise. Hammer from opposite side of weld, so that the weld and added material will be in the folds of the bend. For pieces of ordinary sizes a twelve pound sledge is satisfactory and with a little practice welders can deliver hammer blows with almost uniform force, and number of blows and degree of bend indicate character of weld. See "Testing Welds."

Bernados Process

An electric arc welding process named for its inventor, and more commonly known as the "Carbon Electrode Process." The principle of this process is based upon the fact that if an electrical circuit, through which an electrical current is flowing, is broken the current will continue to flow through the gap left in the circuit until the distance across the gap increases the resistance to the flow beyond the force of the current, and the gases in the gap offer so great a resistance that they are heated to incandescence. How this principle has been utilized in developing the Bernados welding process may be seen in the accompanying



Bernados Process.

diagram. Here, the piece to be welded is made to form part of an electrieal circuit; touehing it, and forming the next part of the circuit is a pointed rod of carbon, which in a pure state has a very high melting point and is highly refractory. To start the welding operation it is only necessary to

turn on the current and then draw the tip of the carbon rod a slight distance (⅛ to ½ inch, depending upon the size and nature of the work) from the metal to be welded. If the gap is not made too large a continuous spark will immediately jump across the gap which thereupon becomes filled with metallic vapors and the metal at the end of the gap is quickly reduced to a molten state. Usually there is insufficient metal in the piece to accomplish the weld and maintain the desired thickness, so a rod of similar composition is melted by the arc and supplies the material necessary to secure the desired thickness. The illustration is not typical of the apparatus used in present day applications of the process, but is reproduced for its historical interest. Complete descriptions of modern apparatus, with instructions and illustrations of the possibilities of this method of welding will be found in the section devoted to the Carbon Electrode Process, in the chapter on "Electric Arc Welding."

"Bertschy"

Trade name for V-Blocks, step-blocks, trucks, etc. Made by Bertschy Mfg. & Engineering Co., Cedar Rapids, Ia.

"Bermo"

Trade name for welding and cutting torches and accessories. Made by Bertschy Mfg. & Engineering Co., Cedar Rapids, Ia.

Beta Brass

A copper-zinc alloy with a copper content of approximately 54 per cent, composed of but one type of crystals all of which are of the same composition. At ordinary temperatures, the normal range of beta brass is from 51 to 55 per cent copper. Quenching from higher temperatures considerably broadens this range. Between 64 per cent copper and 55 per cent copper, the copper-zinc alloys consist of mixed crystals of alpha and beta, the relative proportion of which depends upon the composition and heat treatment. When rapidly cooled from high temperatures (that is, from at or near the melting point) mixed alpha and beta may occur with copper as high as 70 per cent.

Beveling

A weld properly prepared is a weld half completed. Indifferent beveling and poor preparation of parts to be welded is responsible for many failures. Popular opinion to the contrary, this disregard of an elementary principle of sound welding is most apt to occur in the case of an experienced welder, or at least an operator who has been welding for some time, rather than in the case of a beginner. The beginner quite naturally begins his welding education by carefully considering the first basic principle of the art, one of the first of which is thorough preparation. The operator who has been welding for some time and who has been encouraged by a degree of proficiency and success is more apt to grow careless and disregard some of his early training, with resulting failures. These failures he is often prone to attribute to anything but their true cause. So we deem it proper to not only caution the beginner to prepare

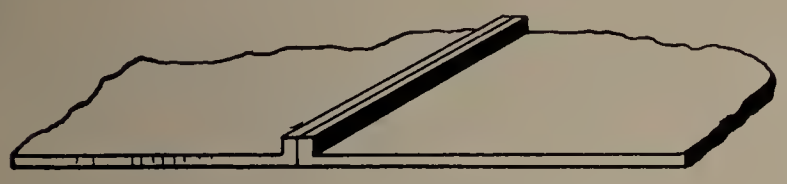


Fig. 1 For 20 gauge and thinner

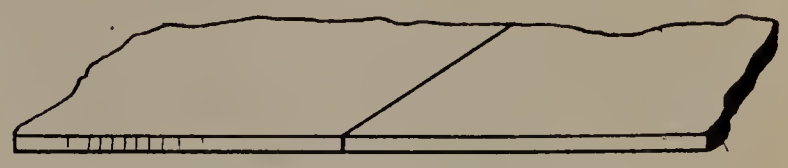


Fig. 2 For 14 to 18 gauge

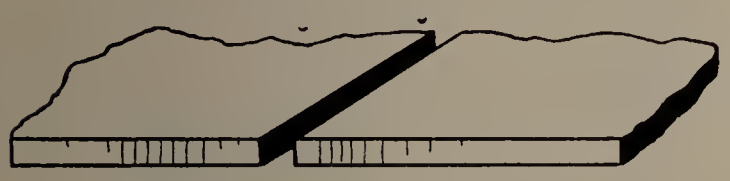


Fig. 3 For 8 to 14 gauge

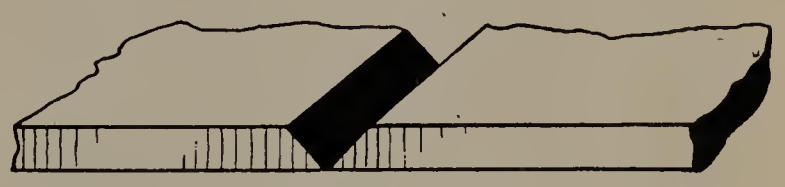


Fig. 4 For 5/32" metal and up

Fig. 5 For heavy sections

Fig. 6 Comparison of preparation

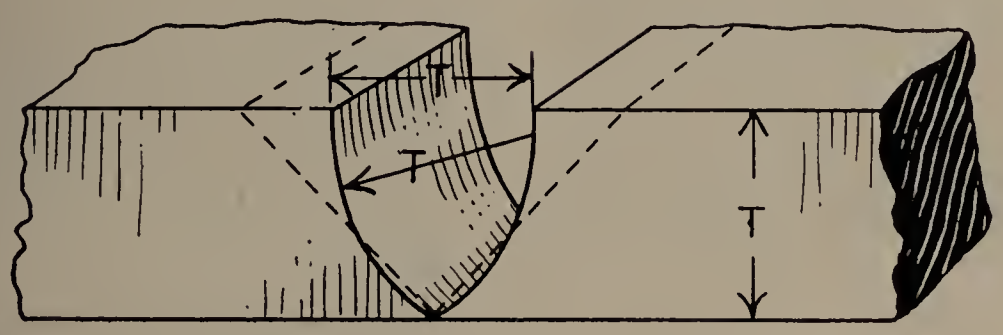


Fig. 7. For very heavy sections

Methods of preparing thin and thick metal for welding.

his work carefully, but to also warn the older operator that no degree of proficiency in the manipulation of the tools of his trade will make him immune from the principle of good preparation of welds.

In preparing work to be welded the very first point to be considered is the proper adjustment, solidity and alignment of the part to be welded. When the weld is finished, should the part be distorted or out of line, the weld is generally useless. The welder should therefore assemble the broken parts with great care.

All metals above ⅛ inch in thickness (except aluminum which is to be welded by the puddling process should be beveled. Failure to secure **penetration** is one of the chief causes of unsound welds. **Surface** welds should be guarded against and if necessary the welder should sacrifice neatness and appearances in favor of a **sound** weld. The welder who cultivates the habit of going to the **bottom** of his welds and securing **complete fusion** will find that as his proficiency develops, to his ability to secure **thorough penetration** and **complete fusion** will be added the ability to turn out neat work.

All metals from ⅛ inch to ⅜ inch, and in some cases ½ inch, should be beveled from one side only, to a 90 degree angle. When possible, pieces exceeding ½ inch in thickness should be beveled from both sides. Beveling pieces exceeding ½ inch in thickness from both sides saves gas, filler rod and time. The reason for this is illustrated. Let us assume that we have a bar six inches long and one inch wide and one inch deep. We divide this bar into six sections, each section one inch long. Assume that we are to cut a bevel in the exact center of the bar—a 90 degree groove from both sides. It will be noticed that exactly one half cubic inch of metal has been removed. .Now refer to the illustration, which shows the same bar, in which we have cut a 90 degree groove from one side only. Here we have cut out exactly one cubic inch of metal. Therefore twice the amount of filling will be required, with attendant costs.

Anything less than a 90 degree bevel does not permit of free access to the bottom of the V. The sides or the top of the bevel are most apt to be melted first and, the molten metal which runs down to the bottom of the V means adhesion and not **fusion.** The welder may take refuge in his ability to **dig** into the bottom of the bevel with the flame, but this practice is objectionable, as the metal is very apt to be overheated and is almost sure to show a crystalline structure, containing pockets of oxide and **non-penetration · cracks.** Welders have been known to turn plates over and **wash weld**

A

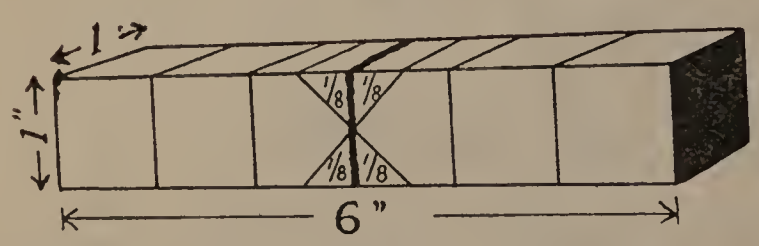


Fig. 8.

the reverse side of the plate. This practice produces no beneficial results and merely camouflages a poor job, as good adhesion is impossible.

In beveling parts to be welded, whether the beveling is to be done from one side, or from both sides, points of contact should be left. This is to aid the operator in preserving proper alignment. These points of alignment will, of course, depend upon the shape of the part to be welded, but if original points of contact are preserved no difficulty will be experienced in restoring the piece to its original proportions.

Insufficient beveling is productive of very unsatisfactory results. A 60 degree angle while the V may extend to the bottom of the plate, is not sufficient. With a bevel of this type it is necessary for the operator to push his metal downward in an attempt to secure adhesion at the bottom of the V. This practice, as previously stated is sure to result in flowing down a part of the sides and top of the V, with a consequent absence of thorough fusion at the bottom. When this

B

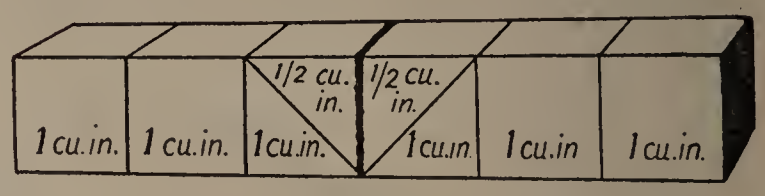


Fig. 9.

practice is followed the metal is mistreated, blow holes occur and the success of the weld is jeopardized.

The bevel should extend to the bottom of the plate and the V should be sufficiently wide to permit the welder to **start complete fusion at the bottom of the weld.** As the weld progresses the angle of the V is sufficiently wide to enable the welder to merge the bottom, sides and filler rod into one homogeneous mass—or in other words, execute a **sound weld.**

The beveled edges to be welded, and also the surrounding metal, should be thoroughly cleaned before welding is started. Welding flux, used when necessary, is intended to carry off impurities, but flux should not be overworked. There are several mechanical means of removing dirt, scale and other impurities, such as the file, scraper, emery cloth, grinder, sand blast, etc. Chemicals may also be used. If a sand blast is used the sand dust should be carefully wiped off the parts to be welded, before the job is started.

Before dismissing the subject of beveling and preparation of welds we might say that the possession of the proper tools for the work of beveling is important. No master welder can afford to hack away at a big bevel with improper tools. Power grinders and chippers are the order of the day. A workman is known by his tools and the manner in which he uses them. See "Design of Weld."

"Big 3"

Trade name for welding equipment and supplies. Made by Big Three Welding & Equipment Co., Ft. Worth, Texas.

Billet Nicking

Heavy billets up to 5½ inch thick may be nicked to a depth of ½ inch to ¾ inch. Cold water is then poured into the key, which starts a crack making it easy to finish the break with the aid of a drop hammer, hydraulic press or a bulldozer.

Bi-Polar Generator

Apparatus for producing oxygen and hydrogen by electrolysis. See "Oxygen."

Bits

The break is usually in the shank. Ordinary practice is to weld with Norway iron, using low heat. Another good way is to weld with bronze, as follows:

Make a bevel the same as usual and give it quite a plenty of reinforcing. Pack the bit when done in powdered asbestos to cool and the job is done except for a little trimming on the emery wheel. With a little practice one can get quite a smooth job.

To replace the screw on the end of a car bit, first put a drop of bronze on the bit

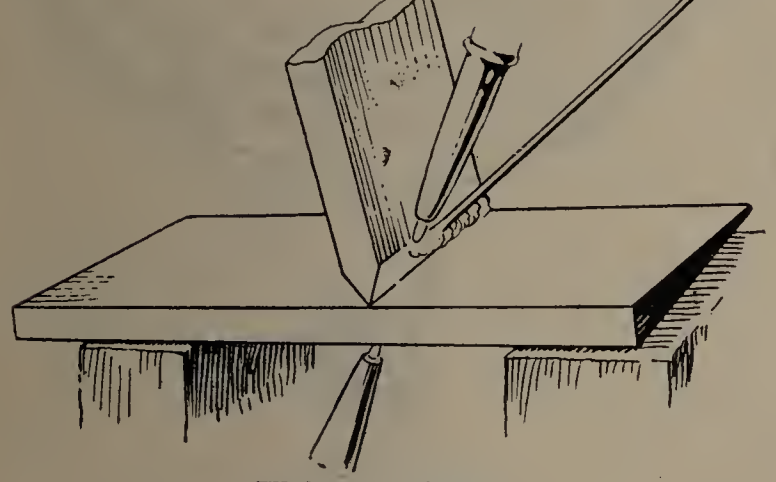
standing upright, then with the screw in a pair of pliers just above it play the flame between the two until the bronze is melted and the screw a dull red, then bring the screw in contact with the bit.

"Black Giant"

Trade name for fabric covered hose. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

Blades

Making T-welds in blades for cutting tools presents a unique problem, in that the thickness of the metal constantly changes as the welding progresses, so that a torch tip large enough for the heavy end of the blade would be too powerful for the part which makes up the cutting edge. One



Welding Blades.

writer recommends the following procedure: Prepare the parts for "single-V" design (See "Design of Weld"): select a torch tip suitable for the smaller section and start welding from the edge; use an auxiliary torch to heat the other end of the weld from underneath. This method is said to give perfect fusion throughout the line of weld, without danger of burning the thin sections.

"Blau Gas"

Blau-gas is the trade name for a combustible gas produced by the destructive distillation of liquid hydro-carbon, such as mineral oils, etc. It derives its name from the German chemist, Herman Blau, the inventor of this gas. The difference between Pintsch gas (see this gas), and Blau-gas, is that whereas Pintsch gas is a mixture of gaseous hydro-carbons that remain gaseous even under high pressure, Blau-gas is a mixture of gaseous hydro-carbons and easily volatile compounds. In order to produce such a mixture Blau utilized a relatively low distillation temperature as compared with the Pintsch process, where a distillation temperature of from 1100° to 1600° F. is used.

Blau-gas has been recommended for both welding and cutting. It is supplied to the trade in seamless drawn steel cylinders, charged to a pressure of 1800 pounds per square inch, with a capacity of 200 cubic feet.

Blau-gas cylinders must be constructed in accordance with Shipping Container Specification No. 3A, now in force, and issued by the Interstate Commerce Commission. These specifications as well as the regulations for its transportation are enforced by the Bureau of Explosives, No. 30 Vesey Street, New York City.

Blowpipe

A term frequently applied to welding and cutting torches. See "Torches" and "Torch Classification."

Blow Hole

A hole or a cavity formed by trapped gas, or by dirt, grease or foreign substances. Blowholes at the point where added material joins original material usually means that the metal was melted too fast. If near the surface they may be due to too rapid cooling. Blowholes are almost sure to result from dirty welding surfaces.

Blow-off Valve

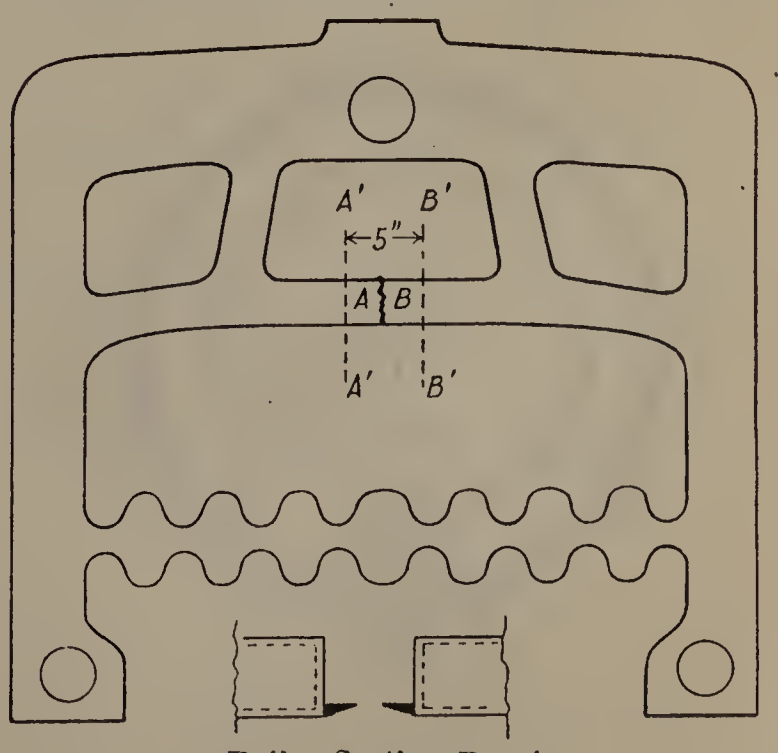
A hand operated safety valve on an acetylene cylinder to clear the chamber of air and acetylene mixture after charging.

Boiler Code Committee

Committee of A. S. M. E. having charge of rules relating to construction of fired and unfired pressure vessels. A sub-committee (welding) is engaged in research concerning autogenous welding as applied to the construction of present vessels. See "A. S. M. E." and "Rules and Regulations."

Boiler Sections

Perhaps one of the most trying repairs that a job welding shop comes in contact with is that of repairing boiler sections. The usual method of welding boiler sections has been to preheat the entire section with the oil burner, or with the oil burner and charcoal. If the crack is on one side only and it is not necessary to turn the section over, the welding may be done without a great deal of discomfort to the welder, however, this is a very exceptional case. Usually, however, the crack extends so that it is necessary to weld while the heated boiler section is in a vertical position. In such cases it is very tedious for the welder also there is danger of the boiler cracking while cooling, and a possibility that there will be a slight expansion or shrinkage so that the push nipples are out of alignment and the boiler can be assembled only with difficulty. The accompanying sketch shows a method which has been used on "hurry-up" jobs that come into the shop when it is desired to do the work right the first time without delaying the work unnecessarily. This repair is made by cutting out a piece of the section, through A'A' and B'B', and welding on cast iron plates to the ends of A and B. On the bottom of the plates a boss is left for the purpose of retaining the fire brick so as not to injure the draft of the boiler. This method not only eliminates extensive preheating but also all possibility of the section again breaking while in use.



Boiler Section Repair.

Although in some sections there will be found an impression that the safety of welding these parts is questionable, it is nevertheless a common and successful practice. One authority comments on it as follows:

"The welding of cast iron heating boiler sections is perfectly safe, if proper preheat-

ing, welding, reheating, and cooling methods are followed. Usually the whole section must be preheated to a red heat, welded, reheated to the same temperature, and packed in loose asbestos or dry sand to cool." See "Boiler Welding."

"Borax-ette"

Trade name for flux. Made by Cortland Welding Compound Co., Cortland, N. Y.

Bottle

A term sometimes used to describe an acetylene or oxygen cylinder.

Bouchayer

An electric spot welding machine, patented in France March 13, 1903. The machine has two transformers, one on each side of the work, and duplex copper electrodes. One spot weld will be made at each operation when the transformers are connected in parallel, and two when the transformers are connected in series.

Bourdon Tube Pressure Gauges

They take their name from that of the inventor (Bourdon) and consist of a housing or cup shaped body, formed of cast or pressed metal, brass, steel or iron, within which is mounted the actuating mechanism. Fig. A shows such a gauge with dial, front glass and glass retaining ring removed. This particular type is known as an **independent movement,** or one in which the entire mechanism is mounted, independent of the case, upon the socket "8" which in turn is held rigidly in place on case by socket holding screws "9". Derangement of the mechanism in applying the gauge is thus minimized. The nomenclature of the constituent parts follows:

1. Case.
2. Tube.
3. End Piece.
4. Link.
5. Sector.
6. Pinion Post or pinion.
7. Movement collectively parts 5—6 together with front and back movement plates, spacing bars, screws.
8. Socket or connection.
9. Socket screws.

Actuating Principle

Pressure admitted through socket "8" into tube "2" dead ended by end piece "3" causes tube to straighten out, in much the same manner as a garden hose lying curved

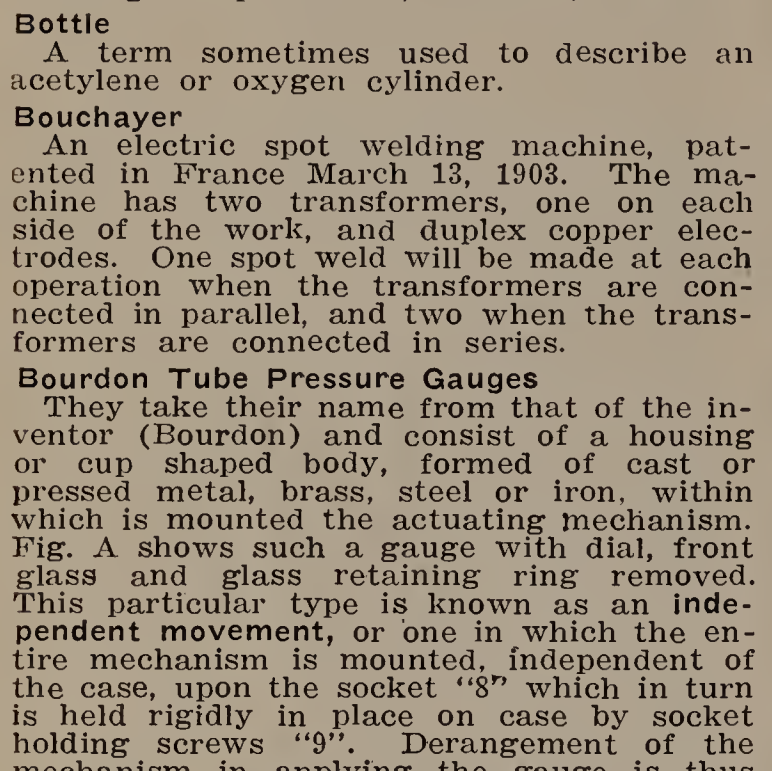


Fig. A.

on the ground tends to straighten when under internal pressure. The motion of free end of tube thus produced is communicated through the link "4" to the sector "5" and by it to the pinion post "6" upon which the hand is mounted. The travel of the hand is governed by adjusting the location of the lower link screw in the slotted sector arm.

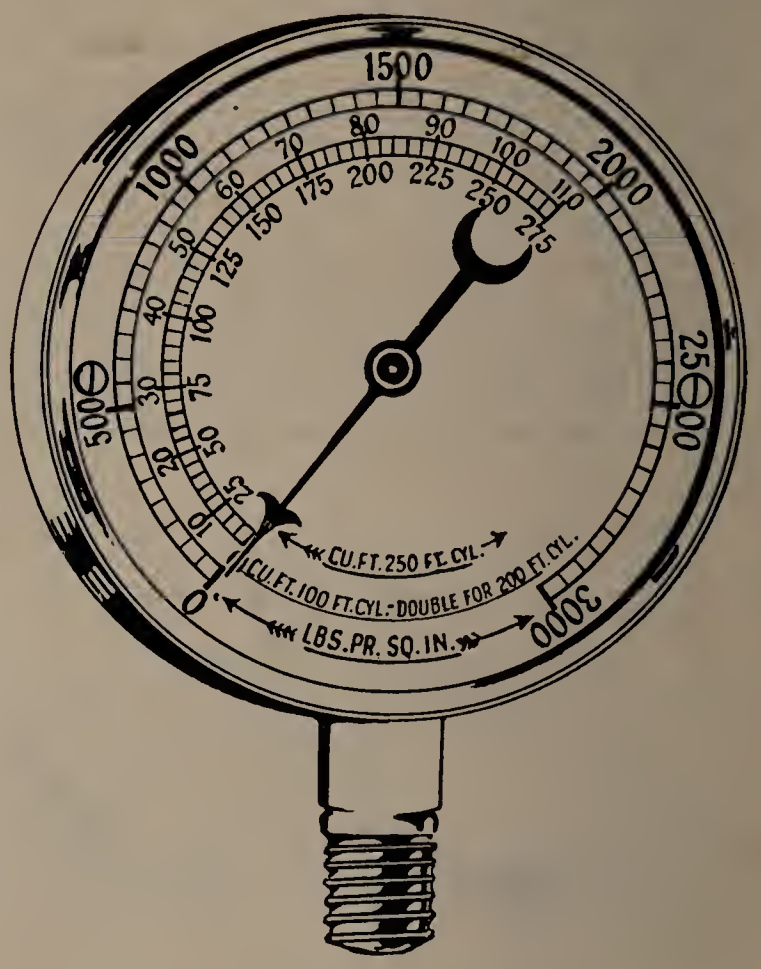


Fig. B.

Tube

The tube varies in thickness according to the diameter of the gauge for which it is intended, and also in accordance with the pressure to be recorded. It must be of such proportions as not to be strained beyond its elastic limit by the application of the maximum average working pressure. General practice is to calibrate a gauge to double its maximum average working pressure. In other words, a gauge intended to record a working pressure of 100 lbs. per sq. in. should be calibrated for 200 lbs. per sq. in. Failure to observe this principle of design causes a gauge to be overstrained, and its tube to assume a permanent set. This is at once detected by the hand which fails to re-

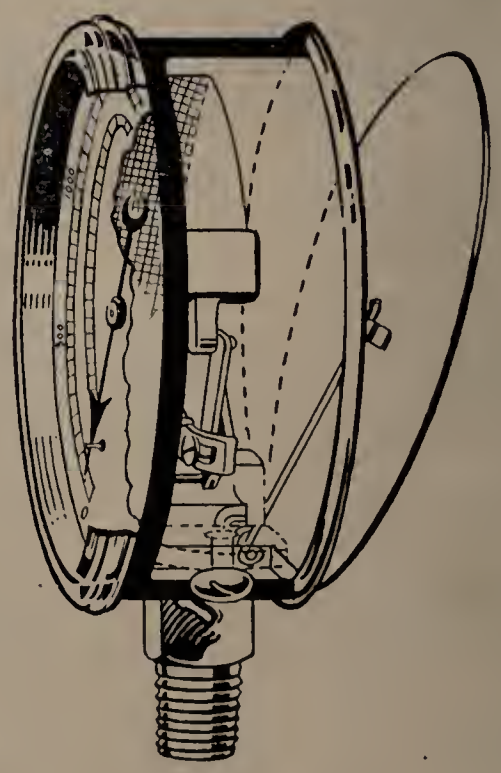


Fig. C.

turn when pressure is released.

Fig. B illustrates a gauge used for gases compressed to pressures approximat-

ing 2000 lbs. per sq. in. Its dial is marked by inner scales which for a perfect gas indicate the actual cubic feet contained in the cylinders in common use for oxygen, hydrogen, etc. These readings are based on cylinders whose gas content are 100, 200 and 250 cu. ft. respectively at 120 atmospheres and 70° F.

High Pressure gauges such as oxygen and hydrogen gauges should be equipped with safety release features, which will insure the escape of gas from a ruptured tube at the same time preventing the blowing out of front glass and dial, with resultant possibilities of serious injury to observer. Side view (Fig. C) illustrates one method of accomplishing this feature. Case is cast solid in front and has a loosely retained closure plate at rear.

STANDARD EQUIPMENT

The usual equipment of oxy-acetylene welding and cutting apparatus employs the following types of gauges:

3½"—3000 lb. for oxygen, hydrogen, etc.
3"—400 or 500 lbs. for high pressure acetylene.
2½"—50 lb. for low pressure oxygen.
2½"—50 lb. for low pressure acetylene.
3"—200 or 300 lbs. for cutting oxygen.

Care of Gauges

The usual care given to fine mechanism is all that is required.

1. Never permit oil to get into any oxygen apparatus. Better yet, keep it out of all oxyacetylene apparatus, and avoid the possibility of explosion.
2. Never apply pressures to gauges suddenly. Try to open valves on cylinders slowly.
3. Do not apply pressures to the full dial calibration.
4. Do not throw on full tank pressures with the regulating screw on reducing valves screws way in. Work up pressure on low pressure gauges slowly.
5. In applying gauges to apparatus use a wrench on square end of connection.
6. Avoid throwing gauges around. You are bound to derange mechanism.
7. Don't try to fix up a defective gauge. A gauge out of adjustment is much worse than no gauge.

"Brazeweld"

Trade name for brazing wire. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago. See Table of Contents, Catalog Section.

"Brazeweld"

Trade name for brazing fluxes, aluminum solders, and welding compound. Made by Braze-Weld Company, 1226 West Fourth St., Cleveland, Ohio.

"Brazier"

Trade name for brazing wire. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

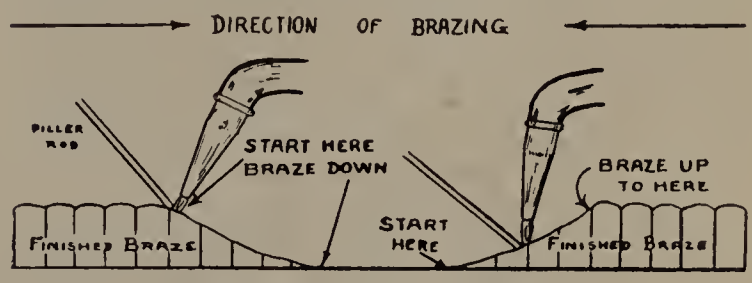
Brazing

Brazing, or hard soldering, is the process of uniting brass, bronze, copper and other metals with molten spelter castings and malleable castings may also be brazed. In fact malleable iron should be brazed, rather than welded. Brazing is nothing more or less than soldering, the solder or spelter having a much higher fusing temperature than ordinary tinner's solder. Spelter used for brazing is an alloy of zinc and copper, usually about equal parts, although the ratio may be changed to suit various metals. The spelter should melt at a lower temperature than the parts to be brazed, otherwise the parts are apt to be melted, causing failure of the job. Brazing may be done in a furnace, but a Bunsen burner or a welding torch is better, as the flame may be directed on the joint only, confining the heat to the parts to be brazed. Parts to be brazed should be fitted together closely. The closer the fit the better. Clean surfaces thoroughly. No matter how tight the fit the molten spelter will penetrate the joint. When ready to proceed sprinkle the joint with a good brazing flux and then play the flame on the part to be brazed. Move flame constantly, so as to simply heat the parts and not cause fusion. When the temperature is higher than the melting temperature of the spelter apply the spelter, which may be in the form of granulated spelter or spelter wire. The latter is preferred because of the ability of applying it where needed. When the spelter flows and runs into the joint it spreads very quickly. When it runs through and appears on the under side of the crack or joint no more is needed. Cover the job with asbestos paper and allow same to cool slowly. For copper and brass use ordinary spelter. For work requiring considerable strength use bronze wire. For malleable castings use bronze welding wire and bronze flux. Ordinary spelter, of about equal parts copper and zinc, melts at about 1600° F. Spelter containing four parts copper and one part zinc melts at about 1850° F. Spelter containing one part copper and four parts zinc melts at about 1300° F. The copper content raises the melting temperature.

The precautions to be observed in brazing heavy cast iron sections are, first of all, to get the job absolutely clean and then keep it clean. The presence of grease and oil is especially to be avoided. Therefore, the surface after having been cleaned should not be touched with the hands or with greasy gloves. Another precaution on the side of cleanliness is to brighten the brass rod with emery cloth before using it. Also, care must be taken not to use too much heat. The line of the weld itself needs to be heated only to a cherry red. It is not necessary to melt it and the bronze should be heated only enough to make it flow so that after cooling, it will have the same color which it had before being melted.

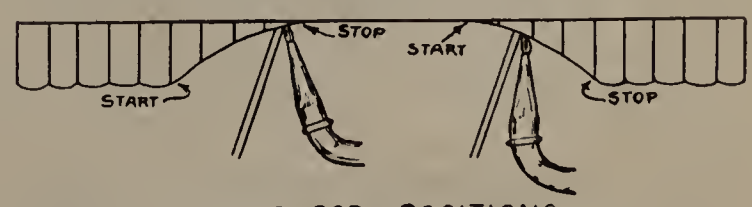
Brazing Cast Iron

Chip out the break thoroughly, and make a good 90-degree Vee from either one or both sides. Cut the metal cleanly instead of breaking out chunks. If the piece is beveled from both sides it requires less filler rod. Use a good tobin bronze filler rod and



FLAT DOWN POSITIONS

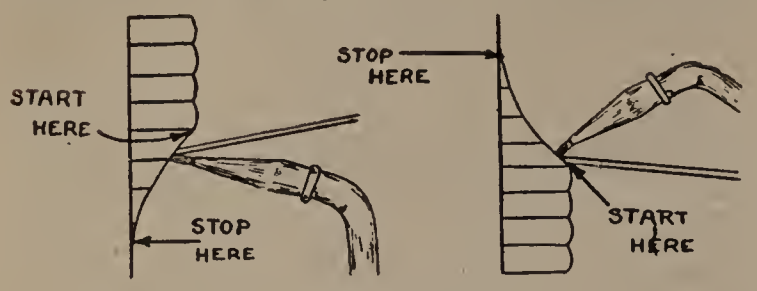
a good flux, finishing the top with manganese bronze. Heat a large section until it is too hot to touch. Having the flux in a flat box, bend a small portion of the filler rod



OVERHEAD POSITIONS

at right angles, heat it, and dip it into the flux box. After that keep it near the flame so that it will stay hot. The correct position for the rod and torch is about the same as for backward welding of steel, both for horizontal work and overhead work. Heat the line of the braze for a short distance until the flux will just wet it, then quickly raise the heat a trifle and apply the bronze. It should flow into the smaller spots like so much water. Just as the flux is applied a very thin spot on the surface is raised to a

high temperature. If too small a tip is used, or the flame is held too far away, a thick section will be heated and this little spot burned. The bronze will not flow then. Overheating the applied bronze will simply



VERTICAL POSITIONS

cause it to come off. It is best to have the zone cover a space three or four times the thickness of the metal. As skill is acquired, this zone can be shortened to increase speed, but the welder should never try to fill up a thick deposit in one place. Keep moving to prevent overheating. After completing the braze, it is a good policy to warm up the work well. The best way to learn this work is to practice on some old cast iron. Give the pieces a bending test to see where they fail. When the braze will pull out the cast iron in large crystals and expose very little of the bronze, a good braze is indicated.

Brazing Copper

Brazing copper without a torch is not at all unusual or difficult. The spelter is kept at the melting heat in a tank and the article to be brazed, after being thoroughly cleaned, is dipped into this tank. It is possible and practical to use city gas and air for this purpose, and if the proper set-up is thought out, very fast work may be done.

Brazing, Electric

If the parts are small enough, and can be handled in the jaws of an electric resistance butt-welding machine, the heating may be done electrically. The operation is similar to electric butt welding except that when the joint has been brought to the brazing heat no pressure is exerted. Instead, the spelter and flux are applied to the joint as in brazing with the torch, and in the electric method the spelter is melted by the heat of the metal forming the joint. This process may be called "Electric Brazing." It has the advantages of keeping the work in sight of the operator at all times and the heat under full control, but is limited to work that can be handled in a butt-welder (or spot-welder) and necessitates the use of a resistance welding machine.

Brazing, Production Work

Where brazing is to be used on a great number of similar jobs, as in production work, a big saving can often be effected by using a furnace for heating the parts. The parts should be properly beveled and then raised to the temperature required for brazing. The flux and spelter are then applied to the joint and the heating continued until the spelter has had a chance to fill the joint completely.

Brazing Wire

A filler rod of brass or bronze used in brazing.

"Brazox"

Trade name for cold drawn brass rod for acetylene welding. Made by Central Steel and Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

Bridge Seam Weld

See under "Line Welding" in chapter on "Electric Resistance Welding."

"Brightweld"

Trade name for welding rods for wrought iron and steel. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

Brinell Test
Test for Hardness

A hardened steel ball is pressed into the smooth surface of the metal to be tested, so as to make an indentation the size of which can be measured. For iron and steel the pressure is applied for 15 to 30 seconds and the hardness is obtained from a table or may be calculated from the formula:

$$A=2\pi R\left\{R-\tfrac{1}{2}\sqrt{+R^2-D^2}\right\}$$

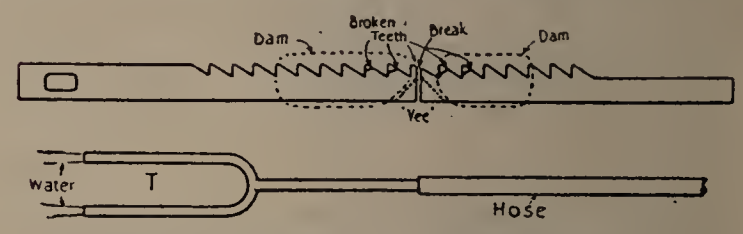
H = Hardness; K = Pressure ball in kilos; A = Area of concavity; R = Radius of ball in mm.: D=Diameter of depression in mm.: H=K/A.

Brittleness

Lack of resistance to effect of shocks, causing cracks and ruptures.

Broaches

Repairing large broaches may involve the repair of the body or the building up of teeth or both. In any case it is usually necessary to harden the teeth after the repair is made. Grind the broken sections to as narrow a working V as possible from the back side, clamp them on a table and line them. Take some asbestos clay and make a dam around each section as close to the V as possible. Fill these with water and make a Tee out of three-eighth tubing, reverse the ends and keep the dams filled up with water while welding using a cast iron flux of carbonate and bi-carbonate of soda. Use one-eighth inch diameter nickel steel welding



Welding Repairs on Large Broach.

rods. After welding break unclamp the Broach and make the dams over again all the while keeping water flowing on it. Build the teeth up with one-eighth inch drill rod and then it is ready for finishing.

To harden the soft teeth without softening the hard teeth was the next problem. Take a piece of five-inch steel pipe five feet long and weld a bottom on one end giving it the appearance of an annealing tube and fill this right up to the top with fish oil. Wire it to the bench so it will not fall from being jarred and have a helper stand on top of the bench and insert the broach as far as the last hard tooth. Then take a smaller tip and play the torch straight across the tooth heating it cherry red. Then have the helper insert it in the hardening pot.

"Bronzeweld"

Trade name for drawn Tobin equivalent welding rod. Made by Steel Sales Corporation, Jefferson and Adams Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Bronzox"

Trade name for bronze welding rod and bronze welding flux for acetylene welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Brooks"

Trade name for acetylene generators and welding and cutting apparatus. Made by Brooks Machine Co., Wichita, Kansas.

"Brown"

Trade name for high temperature recording instruments. Made by Brown Instrument Co., Philadelphia, Pa.

B. T. U.

The unit of quantity of heat used in the English speaking countries is the British thermal unit, which is the quantity of heat required to raise the temperature of one pound of pure water one degree F. The French thermal unit, called calorie, is the quantity of heat required to raise the tem-

perature of one kilogram of pure water one degree C. One calorie=3.968 British thermal units. One British thermal unit=0.252 calorie.

"Buckeye"

Trade name for acetylene generators and oxy-acetylene welding supplies. Made by Buckeye Welding and Supply Co., 1544 W. Sixth St., Cleveland, Ohio.

"Buckeye"

Trade name for acetylene generators. Made by The Macleod Co., Cincinnati, Ohio.

Buckling

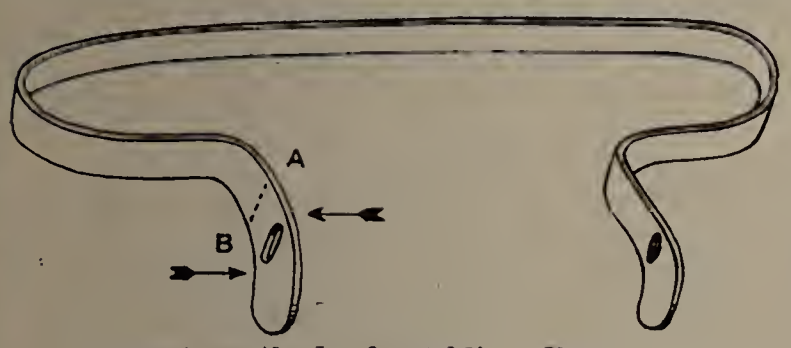
Distortion of sheet metal when welding, caused by contraction of the metal.

"Buffalo"

Trade name for preheating torches and brazing equipment. Made by Buffalo Dental Mfg. Co., Buffalo, N. Y.

Bumpers.

Bumpers are made of spring steel and usually break through the weakest part, that is, through the bolthole. If a weld is made on the little stock which is left on each side of the hole, there is not much chance of it holding. It is better practice to



Correct Method of Welding Bumpers.

cut off 3 or 4 inches back from the hole, and weld on a new piece of plate steel the same thickness as the bumper stock, then taking the broken end as a pattern, mark and cut out a new end with the cutting torch.

Bunsen Burner

A gas torch largely used for laboratory work. A combustible gas is mixed with air before the zone of combustion is reached. The air is introduced through a tube at the base of the burner and the mixture burner at the mouth of the tube with an intense blue flame. The temperature of the flame depends upon the gas used and the pressure.

"Burco"

Trade name for oxy-acetylene welding and cutting apparatus. Made by Burdett Mfg. Co., 309 St. Johns Ct., Chicago, Ill. See Table of Contents, "Catalog Section."

"Burdett"

Trade name for oxygen and hydrogen. Made by Burdett Mfg. Co., 309 St. Johns Ct., Chicago, Ill. See Table of Contents, "Catalog Section."

"Burk"

Trade name for electric arc welding equipment. Made by Burk Electric Co., Erie, Pa. This apparatus is successor to "C & C" arc welding machines.

Burning

A term often improperly used to describe the process of cutting. The use of the word should be discouraged. See "Cutting."

Business Methods for Welders*

No big business was ever built up on slipshod methods or guesswork. No concern ever prospered for any great length of time without giving value received for every dollar. This country is at present flooded with welding shops, both large and small, and the large majority of them are suffering during the present business conditions because there is not enough work to keep all of them busy. Five years from now will see a big change, some of the small shops of today will be big and prosperous, and some of the big ones will be even bigger, some of the small ones of today will still be small, and some of the larger ones will have slipped back, to be classed as "one horse" shops, while many of the present-day job welding shops will in five years have passed out altogether, and their owners will be working for some one else, whom they will probably refer to as "more lucky."

The purpose of this article is to outline one of the main reasons why some welding shops grow big and prosper and why some dwindle down and eventually pass out. This reason can be summed up in the three words, "proper business methods;" those that have them prosper, those that lack them fail.

How Profits Are Made

The basis of all business is to buy a thing at a certain figure and sell it again at a higher figure—thus, making a profit. Between this buying and selling various things must be done to increase the value of the thing first bought. Perhaps you buy labor and with it make changes on other materials you have bought, which increase their value so that you can sell them for a higher price than you paid for them; or perhaps you buy an article in large quantities and by your own efforts or the efforts of those you employ, you find a market for this same article where it can be sold in smaller quantities at a higher price; or perhaps you buy a number of different materials and by the use of labor and machinery, combine them into various articles, entirely different yet more useful which you can sell at a profit; or perhaps you buy a certain kind of skilled labor and by supplying this skilled labor with proper tools and giving it proper supervision, it can perform certain operations which increase the value of various articles or materials. There are, of course, many and varied applications of this principle and some of them may seem rather far fetched, but, as a general rule it holds good.

Now let us see how this principle applies to a job welding shop. In the first place you must buy something. Alright. The ordinary job shop buys three things: first a certain kind of highly skilled labor; second, two gases, oxygen and acetylene; third, various welding materials or rods. The man who buys or has, these three things, can, by proper supervision and direction, form them into a service. This service can then be sold to another man who has a broken article or some pieces of iron or steel to be cut up. This service of welding or cutting will increase the value of the articles or pieces of iron or steel. Because of this increase in value he is willing to pay you a higher price for this labor, gas and welding material than you yourself paid for it and thus you make a profit.

What the Customer Buys

You buy labor, gases and welding materials and by proper supervision and direction, form them into a service which is what you have to sell.

When a man brings a job to your shop to be welded he really offers to pay a sum for the use of your skilled labor, gases and welding materials, which is higher than you paid for them. The difference between what you paid for this service and what he paid you for it is known as "gross profit."

Just how much this "gross profit" should be is a very important item, because there are so many items of general expense which must be paid out of it. To express these many items in a few words they come under two headings "overhead expenses" and "net profit." It is very plain to see that if your "gross profit" is not large enough to cover your "overhead expenses" that nothing is left for "net profit" and as this

**Written for The Welding Engineer by Robt. B. Dyar.*

is the actual and only profit that the owner of the shop makes for himself, it is a very important item.

Net Cost

However, before profits can be figured either "gross" or "net," there is one thing that must be known, and that is the "net cost" of the job that you have done, that is, the actual amount of money that you paid out for labor, gases and materials to do the job. In order to know the "net cost" of a welding job you must keep an accurate record of the labor, gases and materials you have used on that job. You would not attempt to sell anything else unless you knew how much it cost you, you would not **put a price** on an automobile unless you knew how much you paid for it, so why put a price on a job you have welded or intend to weld unless you know just how much it is going to cost you to do the work? Of course after years of experience a man can make a fairly accurate guess on small work, but even the best are often fooled by some of the bigger jobs, and it is in the big jobs that most of the profits are made and also that most of the big losses have to be met.

Gross Profit

If you will prosper, you must know the "net cost" of the jobs you weld, then to this "net cost" all you need to do is to add your "gross profit" and the deal is closed. Yes, it sounds very simple, but—it is in that little item of how much "gross profit" to add that most of the trouble comes. If you add too much you have a dissatisfied customer, which is worse than having no customer at all. If you do not add enough gross profit you will not have enough to pay for your overhead expenses and your own profit, and your business will go on the rocks.

Overhead

Of the two items which go to make up "gross cost" namely "overhead" and "net profit" it is the item called "overhead" that gives most welding shops trouble, yet it is a **most** important factor, so let us take this item of "overhead expense" and see just where we stand on that. The chart, (Fig. 1) shows most of the items that will ordinarily come under this head in a welding shop, although the items in various shops differ. We first stated that you buy skilled labor, certain gases and welding materials, which by proper direction and supervision you form into a service which is what you have to sell. It is during the forming of the three things you buy into the service which you have actually sold that you incur this item of "overhead expense" which is really composed of a large number of smaller items. To illustrate further. In order for your skilled labor to make use of the various gases and welding materials which you have bought you must comply with certain conditions. You must rent a shop which you must heat in the winter time. You must furnish light to work by and power for your labor to use. You must carry insurance and pay taxes on your property. You must employ certain non-productive help to keep your books and assist in the general work of running your business. You must pay for advertising and selling your product. You must pay interest on any money you borrow and replace articles used in your shop which break or wear out. You must buy various items for your men such as goggles, gloves, flux chalk, oil, charcoal, tools, etc. In other words you must pay out money for various things needed to properly conduct your business and this money or the cost of running your business is what is known as "overhead expense."

The next question is "just how is this 'overhead expense' added to the 'net cost' of each individual job that goes through your shop?"

Figuring Overhead

In order to do this it is necessary to keep an accurate record of the money spent for overhead items. When this is done, it will be found that the amount of money paid out for these items for a specified length of time, bears a certain relation to the amount of money you have paid out for skilled labor, gases and welding materials for this same particular period. Suppose for example that for the first six months of this year you paid out in wages to your welders, and paid out for oxygen, acetylene and welding rods the sum of $1,000.00. For the same six months you paid out for overhead items the sum of $500.00. The $1,000.00 is the total "net cost" and the $500.00 is the total "overhead expense." It is plainly seen from this that the "overhead expense" for this period was just half as much as the net cost in other words the overhead was 50 per cent of the net cost. This 50 per cent is what is known as the "percentage of overhead."

As it is almost impossible to figure out in advance what your "overhead expenses" will be, the generally accepted method is to take the figures for the past six months to work out your "percentage of overhead" and use this percentage for the next six months which follow. For example, you have found that your "percentage of overhead" for the first six months was 50 per cent.

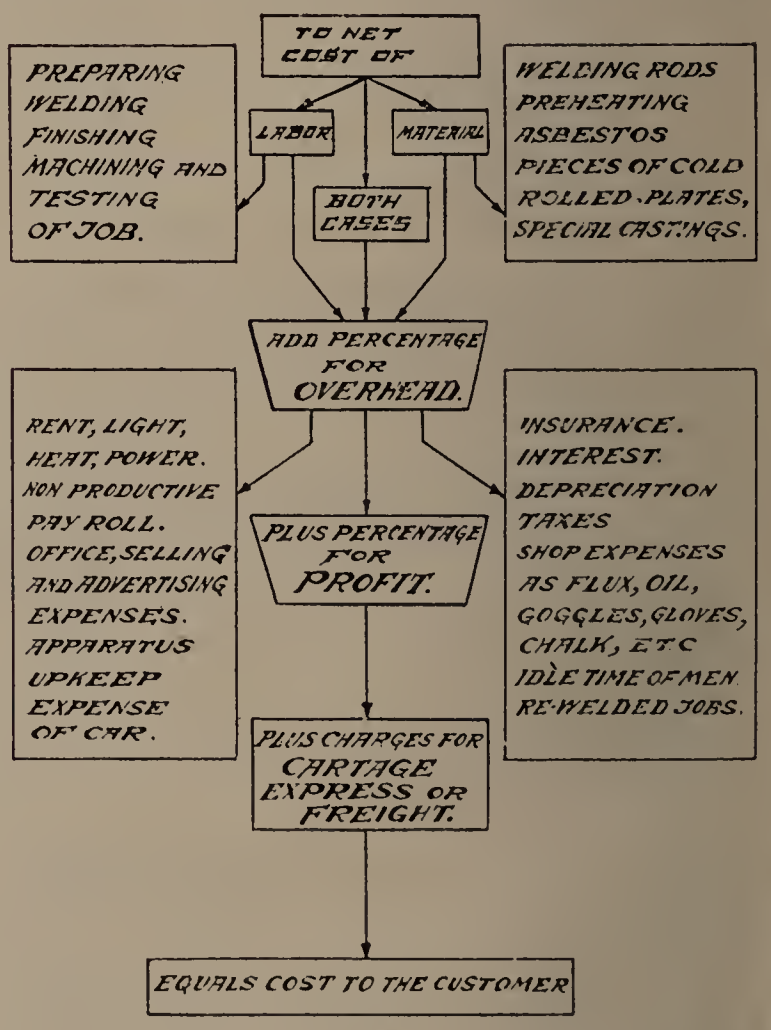


Fig. 1.

Fixing the Price to the Customer

If you have done a job on which the "net cost" figures up to a total of $5.00, (that is you have spent $5.00 for labor, gases and materials on the job), you then know from your figures on your first six months' business that it cost you 50 per cent of your "net cost" to take care of your overhead expense needed to run your business. Then in order to take care of the portion of the overhead expenses which this particular job must pay, you merely add 50 per cent to the net cost of the job, which makes $2.50 added to $5.00, giving a total of $7.50 which is known as the "gross cost" of that particular job as it includes the "net cost" plus "overhead expense;" however, this figure does not include any profit for you, so to

this "gross cost" you must now add your "percentage of profit." In many lines of business this is a certain fixed percentage, so let us assume that you feel the job should pay you 50 per cent, then to the "gross cost" or $7.50 you add 50 per cent or $3.75 making a total cost to the customer of $11.25.

The $11.25 paid you by the customer then divides up as follows: Net cost to you for welding the job $5.00. Overhead expenses $2.50. Net profit $3.25. By figuring your charges in this manner you are using proper business methods and are sure of a profit on every job that goes through your shop.

Play Fairly with the Customer

By using these methods you also gain the confidence of your customer which is the biggest asset a welding shop can have. If your customer feels that he is paying you a fair price for the work you do he will not only bring all of his work to your shop but will tell his friends about you.

The idea of charging a customer "all that the traffic will bear" is wrong, dead wrong. It is not justice to your customer and will sooner or later mean the ruin of the welding shop that does it.

The old method of using guess work in fixing a charge for a job that has been welded is wrong, and no welding shop will grow into a big money making business that uses this slipshod method.

The shop ticket is a practical application of the chart to your every-day business.

On the front is space for all of the information ordinarily put on shop tickets. In addition to this, there are spaces for the person who welds the job to put down the exact amount of TIME, GASES and welding MATERIAL used.

From the chart you will see that this is the information needed from which to build up the price to be charged your customer. This is done in a very simple manner on the back of the ticket.

LABOR—Under this heading there is a space to put down the total time used for welding (this includes preparing, welding, finishing and testing) and if any machine work has been done, there is a space to put down the hours of machine work. The net cost of this labor, or in other words, the rate per hour of the man is then filled in and the total extended into the net cost column.

GAS—The number of cubic feet of gas is then put down. The welder gets this from the high pressure or tank gauge on the oxygen cylinder. The acetylene consumed is always a little less than the oxygen, but for ordinary purposes the amount of both gases consumed can be figured to be the same, so the cost to be filled in for gas is the combined cost of both the oxygen and the acetylene, including the cost of handling the cylinders.

MATERIAL—Such as cast iron, steel, aluminum, brass or tobin bronze (for malleable) filler rod; charcoal, kerosene, oil or city gas used for preheating asbestos paper and any special castings or pieces of bar stock, plates, etc. The amount of this material is taken from the welder's record. The costs are taken from your invoices and are filled in after each item. The total is then extended to the net cost column.

When this is done, add this column up and the result is the NET COST of your job. To this figure add your percentage for overhead, next add your percentage of profit and if necessary add any charges for CARTAGE, EXPRESS or FREIGHT, and the result is the RIGHT PRICE to charge your customers. A price that is right because it gives you a profit and protects your customer against overcharge.

The permanent detailed record furnished by the shop ticket is valuable as a basis for estimates on future jobs and a check on the time of the welder and on the gases and materials used.

Bu-Tane

A clear colorless mobile liquid with a gravity of 100° to 115° B. at 32° F. It has a heating value of approximately 3000 B. T. Us. per cubic foot. The theoretical ratio of combustion is 6½ parts of oxygen to one part of "Bu-Tane." In actual practice, however, the air gives up 2½ parts of oxygen which makes the ratio of combustion 4 parts of oxygen to one of "Bu-Tane." This gas is a product of the gasoline absorption plants, and one gallon of the liquid weighing approximately 5 lbs., yields approximately 8¼ feet of vapor to the pound. Under the rules of the Interstate Commerce Commission, the product is marketed in seamless steel cylinders similar in all respects to the Oxygen cylinders now in use by various oxygen companies; 8 and a fraction gallons of the liquid being placed in each cylinder, consequently, each cylinder contains 330 cubic feet.

This gas is recommended for steel cutting for use in Bunsen Burners in laboratories, for house lighting and cooking, for use with the pumpless blow torch which is a torch manufactured in Pittsburgh, Penna., to take the place of the gasoline blow torch which is so commonly in use. In the pumpless blow torch, no priming nor pumping of air into the cylinder is necessary, a cock is turned which releases the vapor, and a flame temperature of 2200° is obtained instantaneously. As soon as the burner is warm another cock is turned, the vapor pressure in the top of the burner being ample to siphon the liquid into the burner.

No. 1 "Bu-Tane" is used for the pumpless blow torch, this develops a vapor tension of approximately 150 lbs. to the square inch at 70° F., this product is also recommended for use in Bunsen Burners.

For steel cutting, No. 2 "Bu-Tane" is sold which develops a vapor tension of approximately 650 lbs. per square inch at 70° F. The No. 1 gas can be used in the pumpless blow torch at a temperature of 10° to 15° below zero. The No. 2 gas will vaporize at a temperature of 40° below zero.

Butt Seam Weld

See under "Line Welding" in chapter on "Electric Resistance Welding."

Butt Weld

A butt weld is one in which two plates or surfaces are brought together edge to edge and welded along the seam thus formed. The two plates when so welded, form a perfectly flat plane in themselves excluding

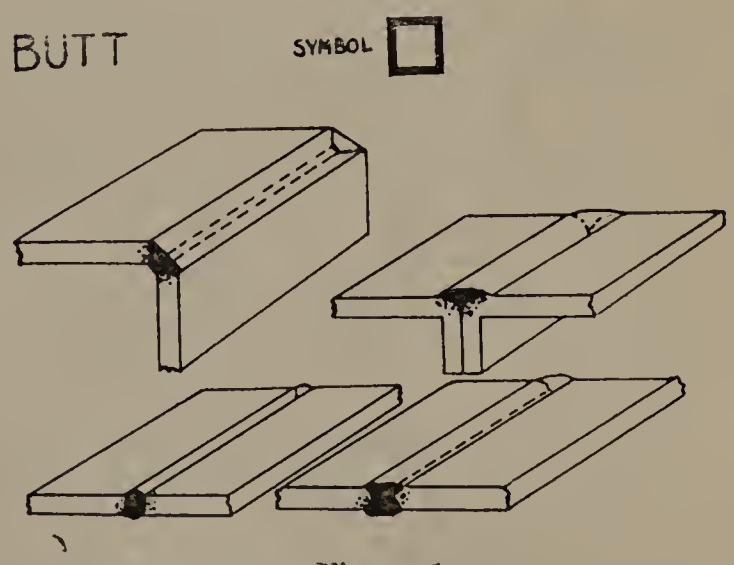


Figure 1.

the possible projective caused by other individual objects as frames, straps, stiffeners, etc., or the building up of the weld proper. Figure 1 illustrates this.

Butt Welding (Electric)

See chapter on "Electric Resistance Welding."

By-Pass

A passage in a cutting torch connecting the oxygen supply and the preheating oxygen tube.

—C—

"C & C"
Trade name for electric arc welding equipment. Formerly made by "C & C" Electric Co., Garwood, N. J.; now sold by Burk Mfg. Co., Erie, Pa. See "Burk."

"Caddo"
Trade name for acetylene generators. Made by Caddo Mfg. Co., Anadarko, Okla.

Calorene
Calorene is the trade name for a combustible gas produced by the catalytic dehydration of ethyl alcohol. It is a homogeneous unsaturated hydro-carbon gas with a small admixture of other hydro-carbons, due to the process of manufacture. Analysis of the Calorene shows a carbon percentage of 86, and a hydrogen percentage of 14. Like all other combustible gases, with the exception of Acetylene, Calorene can be safely compressed and stored as a free gas, no filler being required in the cylinder. It's explosive range is from about 4 of Calorene and 96 of Air to 14 of Calorene and 86 of air.

Calorene is recommended by the manufacturers principally as a cutting gas, and no claims as to its use for welding is made. It is supplied to the trade in seamless drawn steel cylinders with a charging pressure of 1250 pounds per square inch, and a capacity of 210 cubic feet.

Calorene cylinders must be constructed in accordance with Shipping Container Specification No. 3A, now in force, issued by the Interstate Commerce Commission. Regulations for the transportation of these cylinders has also been issued by the same body, and the enforcement of these rules has been given to the Bureau of Explosives, No. 30 Vesey Street, New York City.

Calorie
Amount of heat given up by one gramme of water in cooling 1° C.

"Camograph"
Trade name for mechanically operated cutting torch. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

"Campbell"
Trade name for blacksmith material and tools. Made by Campbell Iron Co., St. Louis, Mo.

"Canadian"
Trade name for Calcium Carbide. Made by Shawinigan Products Corporation, 169 Fifth Ave., New York, N. Y.

Cap
A metal hood which screws over the cylinder stop valve to prevent damage to the valve when the cylinder is in transit.

"Carbic"
Trade name for cylindrical cakes of compressed carbide. Made by Carbic Mfg. Co., Duluth, Minn. See Table of Contents, Catalog Section.

"Carbolite"
Trade name for calcium carbide. Made by the American Carbolite Co., Duluth, Minn. Distributed by the American Carbolite Sales Co., Duluth, Minn.

Carbide of Calcium*
As early as 1836 Edmund Davy, an English chemist, observed that a by-product which he had secured incidentally to the production of metallic potassium, was capable of decomposing water with the evolution of a gas which contained acetylene. In 1862 Woehler, the most famous chemist of his day, announced the discovery of the preparation of acetylene from calcium carbide, which he had made by heating to a very high temperature a mixture of charcoal with some alloy of zinc and calcium. The product could decompose water, like Davy's compound, and yield a gas containing acetylene. Thus the phenomenon which had been observed but not understood by Davy was explained and published by Woehler, and to him belongs the honor of the discovery of calcium carbide and of acetylene. Woehler further pointed out that the new gas burns with a brilliant but very smoky flame, and announced several other characteristics, though it remained for Berthelot, in the same year, to study and describe these new compounds exhaustively.

Then for nearly thirty years these two substances seem to have been practically forgotten. During all this time acetylene was procurable only by the tedious methods which the early discoverers had used, with the result that even its name was known only to students of science, and it is perfectly safe to say that up to 1892 few even of the professional chemists of the world ever saw an acetylene flame, much less dreamed of it as a commercial possibility.

But with the development of the modern electric furnace, whose high temperature places in the hands of the investigator a means of bringing about chemical changes never before known, the laws which govern its formation could no longer remain undiscovered. It was through the instrumentality of the electric furnace that the possibility of calcium carbide as a commercial product was revealed to Thomas L. Wilson, an electrical engineer at Spray, in North Carolina. In May of the above year this gentleman was conducting experiments, with a view to the preparation of metallic calcium, for which purpose he employed an improved Héroult electric furnace with a current of two thousand amperes and thirty-six volts, operating upon a mixture of lime and coal tar. He secured a melted mass of dark color, which on cooling became solid and brittle. Willson is said to have discarded this product, as it was clearly not the material for which he was searching—metallic calcium. It was thrown into a neighboring stream, when to the astonishment of those who saw it, there was suddenly liberated a great quantity of gas which, on being kindled, burned with the now familiar, bright but smoky flame, and gave off quantities of soot which showed that it was not hydrogen, which would be liberated from metallic calcium and water, but a rich hydrocarbon gas. The smelt was repeated and the product submitted to analysis, which demonstrated that the solid substance contained calcium carbide, and the gas, acetylene. Subsequently, on the 16th of September, 1892, a specimen was sent to Lord Kelvin, in Glasgow, with a letter which has since become a famous document in scientific history, since it secures to Willson the honor of being the first to prepare calcium carbide on a scale large enough to promise commercial results.

Thus, calcium carbide is no new thing, since it has been known for the greater part of a century, but the possibility of its manufacture in quantity dates only from these experiments at Spray, in 1892.

To be sure, the French chemist Moissan and others were occupying themselves with similar investigations during the same time, and Moissan in particular has communicated to the world the results of a thorough study of this and other carbides. True it is, that there has been a legitimate controversy between the supporters of the French savant and the friends of the American experimenter, with regard to the right of priority of discovery, with the result, after the question has been thoroughly investigated, that

*By G. G. Pond, Ph. D., in "Bulletin of the Department of Chemistry," Pennsylvania State College, 1917.

scientific men do not fail to agree that to Willson belongs the honor. The German government has acknowledged it in a most substantial way, by annulling the German patents first granted to Bullier. Thus, through the incidental study of a by-product, and as the result of a chance accident, was the industrial possibility of calcium carbide discovered and made known to the world. To-day calcium carbide and acetylene are familiar terms upon the lips of all the people of every civilized country of the globe. Experiments were continued during the years 1892-93, which demonstrated the practicability of acetylene as a means of illumination and led to the establishment of the Willson Aluminum Company at Spray in the spring of 1895, when the first factory in the world for the manufacture of calcium carbide was installed.

By a carbide, those who familiarize themselves with the concise language of science understand nothing more nor less than a compound or substance composed of charcoal and a metal. But these two parts are so blended into each other, chemically combined, that the characteristics of both are entirely lost in the properties of the product. The carbonates are an entirely different class of compounds, containing oxygen in addition to carbon and a metal, possessed of entirely different physical and chemical properties, and are in no way to be confounded with the carbides. Limestone and dolomite are natural illustrations of carbonates.

Hydrocarbons and carbohydrates are similar and related terms, suggesting the element carbon, because carbon is contained in both of these classes of compounds. Hydrocarbons are composed of carbon and hydrogen only, and there are many thousands of these in existence. Crude petroleum is a mixture of many hydrocarbons; benzine, gasoline and kerosene are therefore hydrocarbons; acetylene itself belongs in this class as we shall shortly see. The carbohydrates include such compounds as sugar, starch, gum, glucose, cellulose, etc., and all contain oxygen in addition to carbon and hydrogen.

Let us not lose sight of the fact above mentioned, that a carbide is composed of carbon and a metal, and nothing else. So far as we know, a carbide of every metal may exist, and many of these are known. Thus potassium carbide, a substance containing potassium and carbon only, has been thoroughly studied and the results published; the same is true of sodium carbide, which is a substance containing nothing but sodium and carbon; we can read, if we wish, about the carbides of barium and of aluminium, of magnesium, copper, silver, etc. Carbides of iron, or iron carbides, play an important role in the metallurgy of iron and steel, but the two carbides which are of leading commercial importance are those of silicon and of calcium. The former constitutes carborundum, a most useful and highly valued abrasive material, while the latter is of importance for only a few valuable properties which it possesses in itself, but chiefly because from it can easily be made the valuable illuminant acetylene.

The carbides, as a class, are solid substances, not easily melted, uninflammable, hard, unattractive in appearance (carborundum is an exception to this), and about two and a half times as heavy as water. They possess in common no valuable property except that when brought into contact with water, certain of them, but not all, have the power of entering into chemical combination with the water, after the manner in which lime slakes with water, but with copious liberation of bubbles of gas. Of those which do this the one of greatest practical importance, and the cheapest, is the carbide of calcium, or we may use interchangeably at pleasure, with equal propriety, the slightly different name. calcium carbide.

Other carbides than that of calcium have not as yet arrived at any considerable commercial importance. Two or three of them have been suggested to be mixed with calcium carbide for the purpose of producing a slower and less violent reaction, but so little use has been made of them up to the present time that we may omit them from further consideration here.

Carbides do not exist in nature at the surface of the earth, though their existence in the earth's interior may possibly have been a matter of great geological importance, giving origin, as some think, to the natural supplies of petroleum, and to natural gas.

Calcium Carbide in Particular

This compound and its peculiarities should here be described in considerable detail. Deferring the method of its preparation to a later section, it may here be mentioned that calcium carbide is a hard, opaque, crystalline substance known to the chemist as $Ca\ C_2$, which, not to be alarmed at the suggestion of a chemical formula, is merely a shorthand expression for one unit of mass of calcium, the metal which exists in lime, combined with two mass units of carbon, the element of which charcoal is composed. Calcium carbide is therefore nothing more nor less than a compound which contains calcium and carbon only. The calcium in it is about sixty-two and a half per cent and the carbon is thirty-seven and a half per cent of the weight of the carbide. We all know that the common ore of iron, which is so familiar, is composed of iron and oxygen, and yet the compound is far different from the iron which it contains and which we know can be smelted out of it, also very different from oxygen, the air which we breathe all the time; we are quite accustomed to realize that the iron is there in the red ore, and the oxygen is there too, though in a substance having properties quite different from either. It should therefore be no difficult matter for us to understand that calcium, a metal, and carbon, a substance like coal, are both contained in this material, calcium carbide, though the compound is so different from either constituent.

Calcium carbide is generally of a dark brown or black color, sometimes described as dark gray, and sometimes as a bluish black, and often possessing a reddish tinge. If broken while hot, the fracture exhibits considerable iridescence. It is brittle and is more or less crystalline in structure. Its specific gravity is 2.22 to 2.26; it endures heating to redness without melting or suffering other change, though it softens and fuses under electric heat; it will not burn, except when highly heated in oxygen; it looks like a mass of stone. A cubic foot of the crushed material weighs one hundred and thirty-six pounds and in weight, color and many physical characteristics it is frequently compared with granite.

Calcium carbide may be preserved any length of time if kept sealed from air, but the ordinary moisture of the atmosphere gradually slakes it and it becomes changed on long standing into slaked lime, not essentially different from other air-slaked lime. This slaking power gives it a name, which is sometimes heard, Acetylene Lime. It always possesses a penetrating odor, which, however, is not due to the carbide itself, but to the fact that it is constantly affected by moisture, yielding minute quantities of acetylene, which account for the odor. It is not affected by solvents, such as carbon bisulphide, petroleum, chloroform, ether or benzol, but if allowed to come into contact with water, or any mixture containing water, an immediate and vigorous decomposition takes place evolving liberal quantities of gas; it is unaffected by shock, concussion or age.

Carbide is a safe substance to store or

transport under proper conditions. It cannot explode, take fire, or otherwise do harm, being similar to lime in this respect also. Since even the slow action of the moisture ordinarily present in the air will in time render carbide entirely useless, it becomes absolutely necessary, in order to securely preserve it, to pack it in perfectly tight, closely sealed containers, generally drums or cans. Granted protection from water, no substance can be safer or less likely to cause trouble when stored or conveyed from place to place. Lime becomes very hot when acted upon by water; so also does carbide, and the only essential difference is that carbide, when it slakes with water, yields a combustible gas. But this is the very fact which makes it interesting and valuable. Carbide decomposes with water in accordance with the following chemical equation:

$$Ca\,C_2 + 2\,H_2O =$$
Carbide and water yield
$$Ca\,(OH)_2 + C_2H_2$$
slaked lime and acetylene.

An easy calculation shows that sixty-four unit-weights of carbide require thirty-six of water, producing also seventy-four unit-weights of slaked lime and twenty-six of gas. But as gas is more conveniently and commonly measured than weighed, a better statement of the same fact would be: A pound of absolutely pure carbide yields five and one-half cubic feet of acetylene. Yet absolute chemical purity is not a practical commercial possibility, and it is natural to suppose that commercial products of different manufacturers will vary in purity. Calcium carbide is no exception. Special reasons for this will be observed later, but in practice good carbide may generally be expected to produce never less than four and a half cubic feet, measured at ordinary temperature, and rarely more than five and one-fourth cubic feet per pound of carbide; it may ordinarily be calculated at five. It is important to remember that the exact proportional weights of water and carbide must always enter in combination, i. e., sixty-four of actual carbide to thirty-four of water, be it ounces, pounds or tons; also that the same proportional weight of acetylene must always result. Any apparent exception can only be due to impure carbide, loss of gas, or failure to secure complete consumption of material.

The evolved gas does not take fire of itself but is easily lighted. Let anyone take a tumbler of water and drop into it a piece of carbide, the size of a pea, then let him light the bubbles of gas as they rise to the surface. In no way is it easier to secure a practical knowledge of the characteristic properties of this wonderful stone. The gas burns with a bright light, not brilliant, for it needs control to bring out this property, and much smoke. In fact, soot in solid flakes may be seen floating through the air when the experiment is performed in this rough way. While carbide, as stated above, is not inflammable, nor possessed of any explosive property, such as is sometimes erroneously attributed to it, it might, by finding access to water in a closed vessel, create such a pressure as to burst the vessel, and it is not impossible that the heat generated might cause an ignition of the gas with resultant disaster. But any such condition as water and carbide gaining access to each other in a confined space is most improbable, could only occur by intention, and may be dismissed from the list of possible accidents.

When water is sprinkled or sprayed upon carbide, in not excessive quantities, the resultant slaked lime is left in a perfectly dry and dusty condition, occupying considerably more space than the original carbide. When more than enough water is employed, the residuum will, of course, be wet, either pasty or thinner if large excess of water is employed.

In the manufacture of carbide it is well to remember that the materials employed are among the most refractory ones which we know. Lime is so infusible that it is frequently employed for the material of crucibles in which the highest melting metals are fused, and for the pencils in the so-called calcium light, because it is capable of withstanding extremely high temperatures. Carbon is the material employed in the manufacture of arc lights and other electrical appliances as well, partly for the same reason. Yet in the manufacture of carbide these two most refractory substances must be forced into combination with each other.

It is the excessively high temperature attainable in the modern electric furnace, five to seven thousand degrees Fahrenheit, which alone accomplishes the combination of these elements to form calcium carbide, and it is not necessary to attribute it to the action of any electric force or process. The electric "arc" being formed in the furnace, a thoroughly incorporated mixture of ground coke and lime in right proportion is introduced. The change which takes place is:

$$Ca\,O + 3\,C =$$
Quick lime and coke yield
$$Ca\,C_2 + C\,O.$$
calcium carbide and carbon monoxide.

which means that fifty-six pounds of lime and thirty-six of coke make sixty-four pounds of carbide and liberate twenty-eight of carbon monoxide, a gas which escapes or is burned at the mouth of the furnace. Thus for each pound of carbide made, is consumed a pound and a half or more of a mixture which is something like seven-twelfths lime with five-twelfths coke. Granted pure material there is formed an ingot of very pure carbide, surrounded by a crust of less pure product because partially unconverted. In breaking up, packing and shipping the carbide, this poorer crust is rejected. At first impure materials were employed for the manufacture of calcium carbide, but this resulted in an inferior grade of carbide, which in turn yielded an impure gas, so that at the present time it is everywhere recognized as essential that only materials of unchallenged purity should be employed. It is customary to use quicklime which is ninety-nine per cent pure, and coke of low ash. Both must contain as little sulphur and phosphorus as possible.

"Carbo"

Trade name for welding and cutting torches and apparatus. Made by Carbo-Hydrogen Company of America, Pittsburgh, Pa.

"Carbo-Hydrogen"

Carbo-Hydrogen is a trade name for a combustible gas, that is obtained from the destructive distillation of suitable Hydro-Carbons. An analysis of this gas is claimed to show an average of 85 per cent Hydrogen, and the balance light hydro-carbons. Like Pintsch Gas and Blau-gas (See these Gases) the Carbo-Hydrogen is produced from mineral oils, the apparent difference between the gases being the distillation temperature. Carbo-Hydrogen with its high percentage of hydrogen shows a higher distillation temperature than the other two gases. Carbo-Hydrogen is not a homogenous gas, as from the nature of production it is shown to contain a mixture of hydrogen and a number of gaseous hydro-carbons of varying densities and properties.

Carbo-Hydrogen is specially recommended by the manufacturers for use in the cutting of steel and wrought iron, as also for the welding of Cast Iron, Copper, Brass, and Aluminum, and for lead burning. It is put on the market in seamless drawn steel cylinders. Each cylinder is claimed to contain 200 cubic feet of Carbo-Hydrogen, when

charged to a pressure of 1,800 pounds per square inch.

Carbo-Hydrogen cylinders must comply with Shipping Container Specification No. 3A as issued by the Interstate Commerce Commission and now in force. Proper instructions for the shipment of these cylinders can be procured from the Bureau of Explosives, 30 Vesey Street, New York City, which has the authority to enforce the compliance with Specifications and Regulations.

Carbon

Carbon blocks, rods and carbon compositions, or paste, play an important part in welding operations. Carbon sheets or blocks may be had in various sizes and these sheets or blocks may be shaped as desired. Fig. 1 illustrates one method of using carbon blocks.

The efficiency obtained in vertical cast iron welds makes it possible to perform the

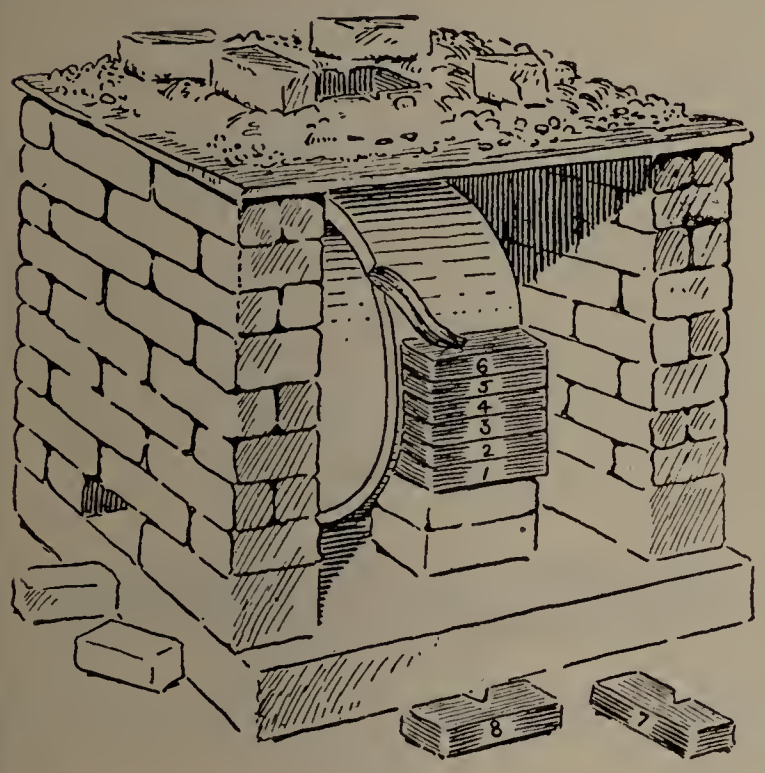


Fig. 1.

heaviest welds on castings without dismantling them; and also to reinforce the weld to any thickness desired, by using a wider carbon block than the weld and grooving out as much as desired, so as to obtain the thicker weld. In building-on work, such as lugs, bosses or broken pieces of castings, a great saving in time, labor and material is obtained.

Instead of the slow process of building on metal on a small vertical edge a carbon,

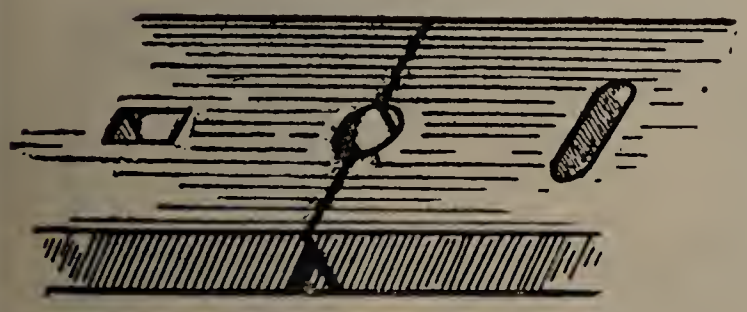


Fig. 2.

cut out so as to correspond with the original lug, is placed against the fracture and the weld is made in a horizontal position, quicker, cheaper and better. With the latter method 60 per cent of labor and gas is saved. No welding rod metal is wasted, as it all melts in the space provided by the carbon edges and casting. To build up a lug, a corner, or any other broken part in a casting with a carbon wall around it, so as to hold the molten metal, does not require as much skill as would be required to perform the same operation without the carbon.

Carbon blocks and plates are far superior to fire clay or fire bricks, which are liable to fuse under the heat of the blowpipe. When carbon blocks are used, the edges of a weld are smooth, regular in shape, which saves machining, while the clay or bricks leave the edges irregular, full of blow holes, requiring machining.

Fig. 3.

Another good feature is that when a cast-iron weld is surrounded by carbon blocks the heat is held at the place where it will do the most good, and the surface of the molten metal is kept from being oxidized by the atmosphere. There is also a small distribution of carbon in the molten metal, which produces a soft surface at the weld.

Although there are a great many sizes of carbon blocks and plates, the most favorable for acetylene welders are: 6"x6"x1": 6"x3"x ½"; 12"x1"x1"; 12"x3"x¼"; and 15"x6"x1".

The carbon rods are used to save redrilling of holes, or to make up a center core. The favorable sizes are ⅜", ½", ⅝", ¾", 1" 1¼", 1½" and 2".

Carbon paste is perhaps even more useful to the welder than carbon blocks. Some manufacturers have put on the market a carbon compound which is in powder form. When mixed with water to the consistency of dough and then heated, it becomes practically fireproof. On this account, it is used extensively with the various welding processes to assist the operators in saving time, material, extensive machine work, and permit the execution of better and more difficult welds. There are many times when it is possible for a welder to rough out a certain missing part or build up a worn spot in a fairly good manner and then after the casting has cooled down grind or chisel the welded portion to size. It will be appreciated that this requires considerable time, not only for the cooling but the machine work

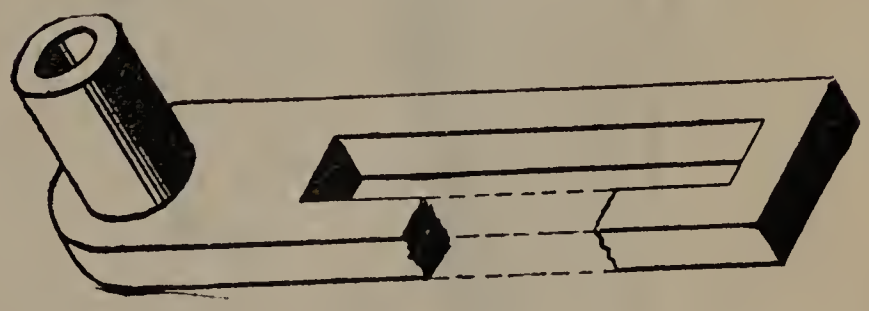


Fig. 4.

as well and it must be remembered that machine work can only be done when the welded part is soft and free from blow holes, otherwise the tools will be ruined.

In Figure 2 we have an ordinary cast iron bar broken through a round hole. It would be possible to make a template, mark the position of the hole, execute the weld, and then drill another hole, but it would be much simpler to fill the hole with carbon compound, after it had been prepared as shown in Figure 3, make the weld and the piece would be all ready for use. In Figure 2 a square hole and one of an oval shape are shown which would not be quite so easy to reclaim as the round hole if machining were necessary,

but they can be just as easily saved with the compound. Again, if this center hole were threaded, the compound could be forced into the threads and the threads saved if due care is taken. In this respect it is best to prepare the weld as shown in Figure 3 and when the metal is molten work it up to the mould with the filler-rod rather than play the flame or arc directly on the mould. It must be remembered that the oxy-acetylene flame and electric arc give

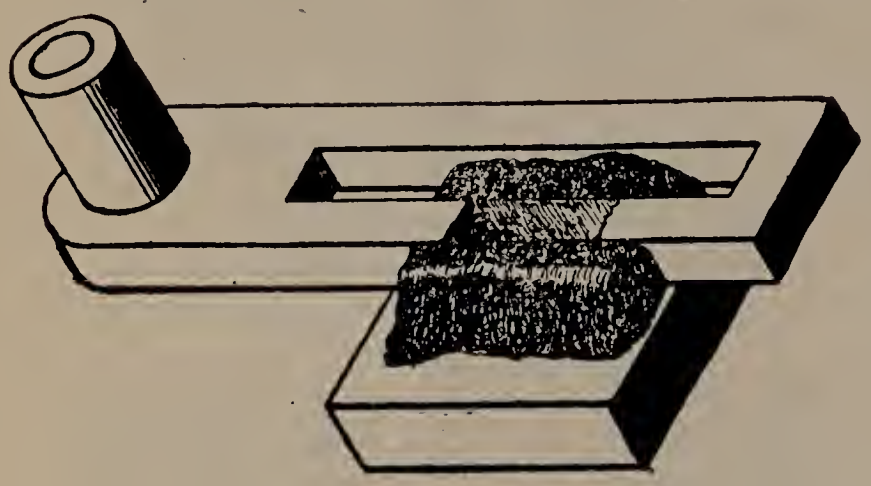


Fig. 5.

off over 6,000 degrees Fah., enough heat to melt any metal, therefore carbon and the usual fire resisting elements will recede to a greater or less extent before the powerful medium. Better results will, therefore, be obtained if most of the work around the mould is done with the end of the filler-rod.

At times parts of machines are brought to the welder for repair and there are pieces

Fig. 6.

Fig. 7.

missing. Figure 4 may be taken as one example. By placing this part on a fire brick and moulding the compound as shown in Figure 5, and firing with the torch (to bake) the missing part can be very easily supplied and a finished job executed very rapidly.

In Figure 6 we have a problem which is very much the same as in the preceding figure. The end of a leg or arm has been broken and is entirely missing. An impression can be taken from one of the other legs or arms if they are available and a new part built up. In this respect the tools

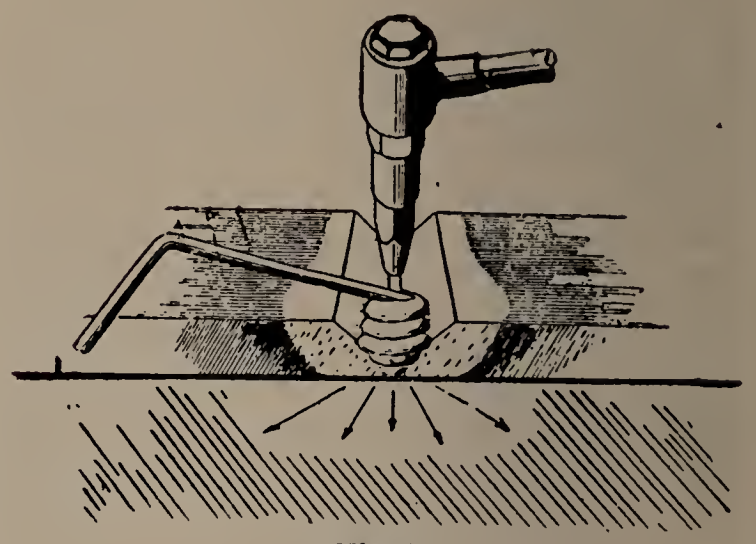


Fig. 8.

shown in Figure 7 will come in handy whenever moulds are to be made.

A quarter inch round rod about ten inches in length is shaped in a spoon-like manner as illustrated, one end being pointed and the other flat.

There are many welders of cast iron who would not think of plunging their hot weld in cold water for fear of chilling it and making it brittle. Yet these same welders will be found using a heavy metal slab as a face plate to line their work up on, somewhat as shown in Figure 8. Their welds

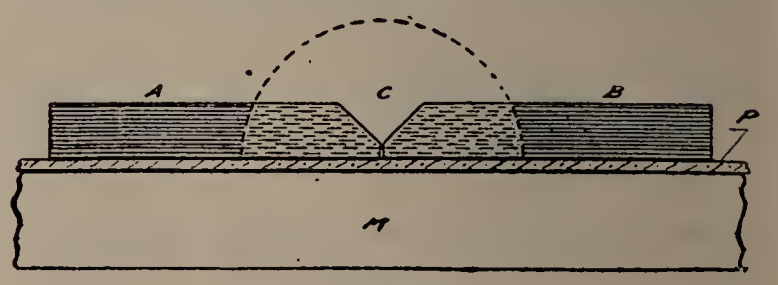


Fig. 9.

will be hard, brittle, and full of blow-holes for they are unconsciously chilling their weld. If they will notice closely, they will find that the minute their torch is removed, their weld will turn black, showing that the heat is being conducted away as the arrows in the figure would indicate and the same result is obtained as when the weld is plunged into cold water. In both of the preceding cases chilling is occasioned by rapid cooling. It is possible to overcome

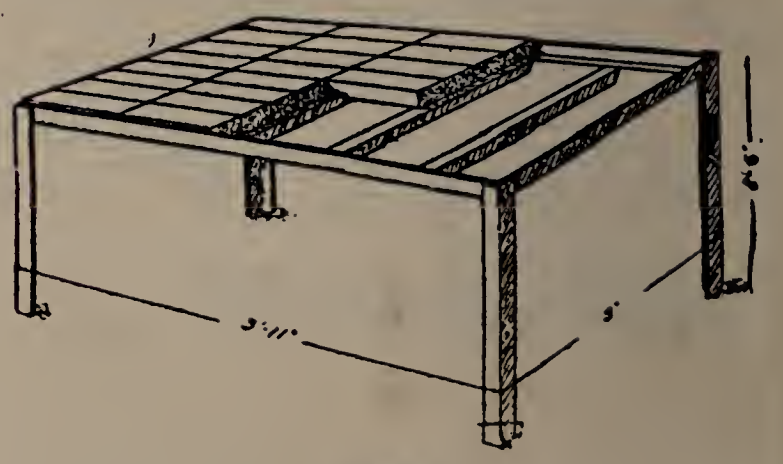


Fig. 10.

much of this trouble and at the same time keep the work in alignment by covering the metal slab with asbestos paper, as illustrated in Figure 9, wherein we have (M) representing the metal slab; (P) the asbestos paper; (A) and (B) the parts to be welded, and (C) the heated zone.

A fire brick top table is the best medium

for use in a welding shop where all around welding is to be done, for preheating may be done right on the table and there is no danger of chilling any welds. The simplest way of constructing a table of this nature is shown in Figure 10.

While most welders concede that the fire brick top table is the logical one for the welding shop it is not as popular as it should be on account of the difficulty experienced in lining up the work. The use of shims and other mediums to accomplish this end is not entirely satisfactory. By using compound, however, all of these troubles will be quickly overcome. If a broken casting is to be placed in alignment, a few

Fig. 11.

fire bricks can be scattered about the welding table and daubs of compound placed on each brick as shown in illustration 11.

The work is then placed upon the compound which acts as a cushion and if one part is too high or low, a straight edge will soon show where the trouble is, and that part raised or pressed down to conform with the other part. See Figures 12 and 13.

In welding aluminum crank cases ofttimes it is necessary to preheat them and in so doing, if they are not resting evenly and supported at all points uniformly they are

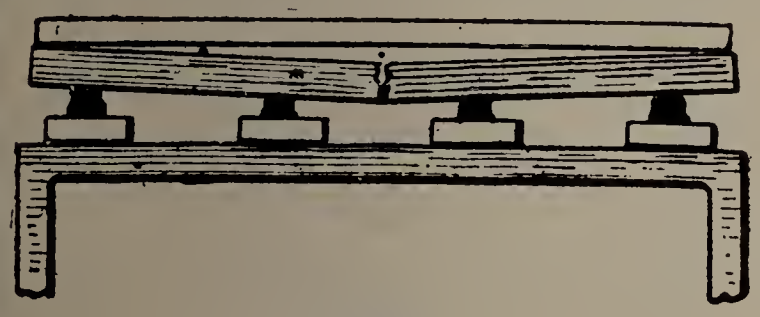


Fig. 12.

apt to sag when heated as aluminum loses all of its strength when heated. Hack saw blades are sometimes used as shims in adding charcoal or other fuel, these shims are sometimes disturbed without the knowledge of the welder, permitting some part to sag and render the job useless. It is much better to have some kind of a medium which can be entirely depended upon in work of this kind. Compound will be found a solution. A few bricks placed about the welding table with daubs of the compound upon them will form an excellent cushion into which the ordinary crank case can be pressed and the welder then knows it is

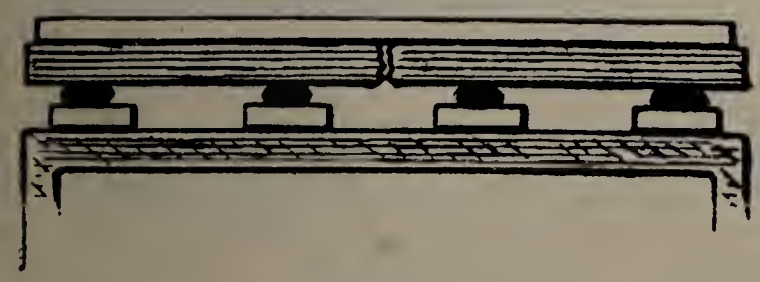


Fig. 13.

supported uniformly and there will be no chance of its sagging. A better idea may be had by referring to Figure 14.

When a part is missing in an aluminum crank case it is sometimes in a position where backing up is quite necessary and in cases of this kind it is advisable to use some sixteen gauge sheet copper and form it as desired. Figure 15 gives one example wherein (A) represents the sheet copper

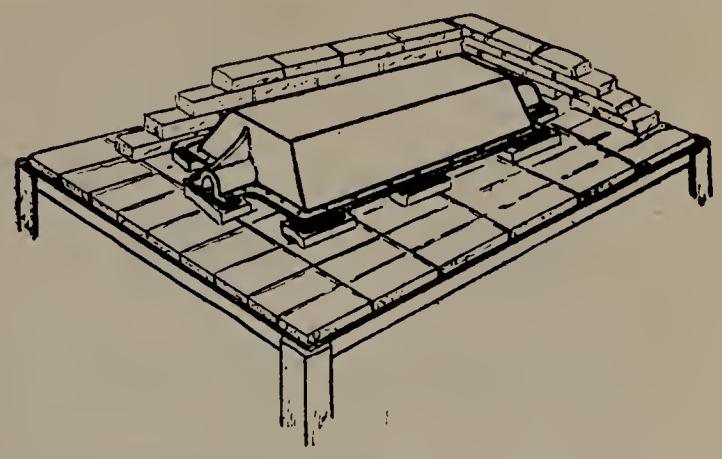


Fig. 14.

and (B) the compound. The upright rods are not springs but are merely coiled to take care of any contraction and expansion which might set up during the preheating or welding operation. In Figure 16, we have a similar problem wherein a copper plate and compound are used when in a slightly different manner. The compound is set upon the top of one brick, the copper sheet is

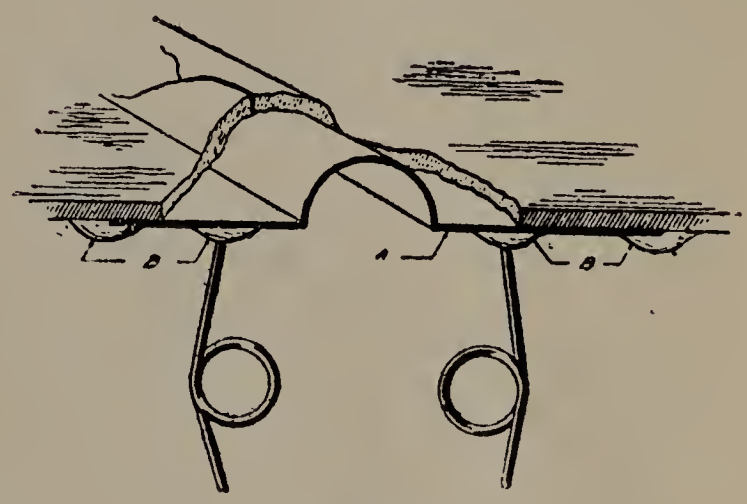


Fig. 15.

placed above the compound and then the crank case is set down over the sheet, thus insuring a rigid foundation upon which to work.

It is quite often necessary that the welder be called upon to execute what is commonly known as an accommodation job. The parts to be welded are usually small, and must be joined at such an angle that much time and patience is required before the actual welding occurs. Ofttimes just as the welding

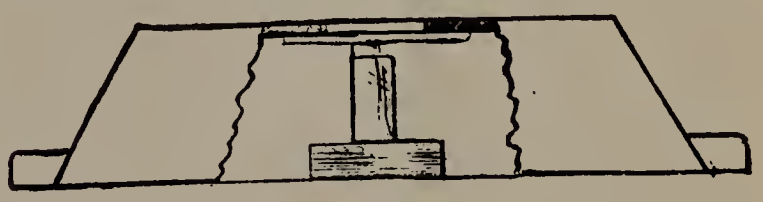


Fig. 16.

torch is applied the parts which have been balanced very sensitively are blown apart and are much too hot to pick up and place in position without first allowing them to cool. This performance may occur three or four times before the welder is successful in fusing the two parts, and then the size of the job will warrant him making only a nominal charge to his customer. How much easier it would be with compound handy, to place two daubs on the top of a fire brick and imbed the parts to be welded as desired. It then only takes a minute to do the welding, thus saving much time and patience. Figure 17 may express the idea. In Figure 18 is shown the use of carbon paste for making molds when the welder

has to build up a broken tooth on a gear wheel.*

Carbon Burning

When pure oxygen is brought into contact with the carbon which collects in the combustion chamber of a gas engine, and the carbon ignited, the oxygen rapidly consumes it. This method of removing carbon is used

Fig. 17.

extensively because of its simplicity and thoroughness.

Remove the wiring and other appliances that are likely to be injured. Shut off the gasoline pipe and drain the carburetor. Remove the spark plug or valve cap on the cylinder to be cleaned. Place the piston in the firing position, that is, the piston at the top of the stroke and both valves closed.

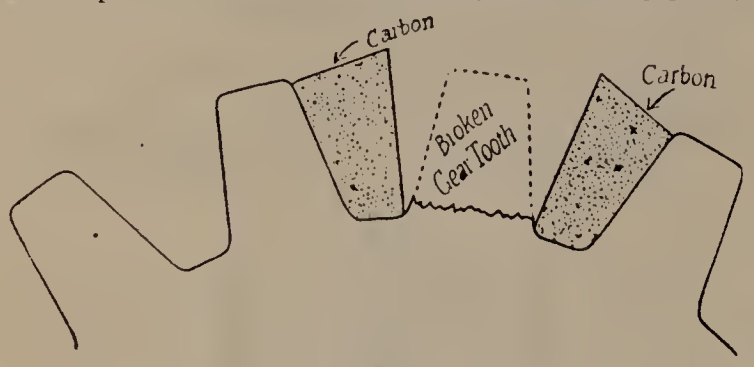


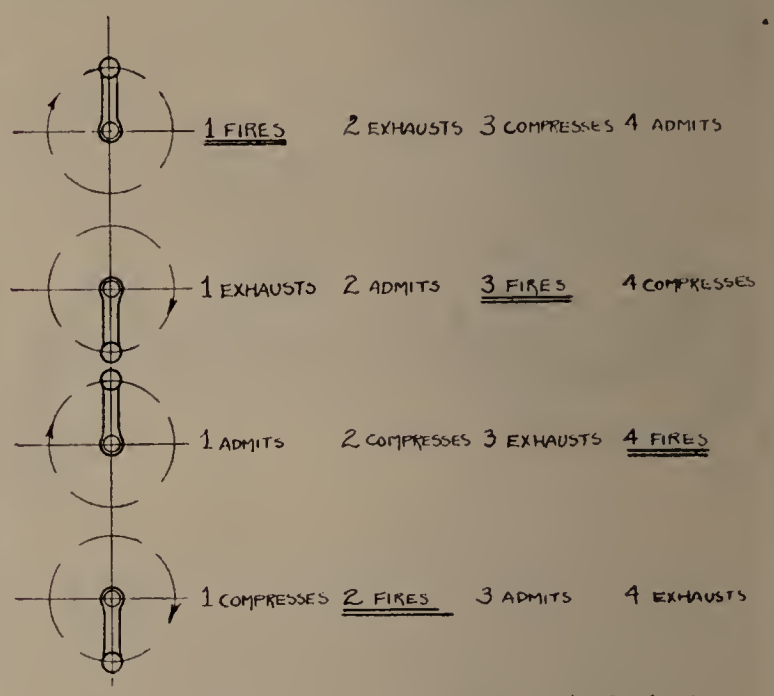
Fig. 18.

Turn down the adjusting screw on the oxygen regulating valve until the gauge shows about twenty or thirty pounds pressure. Drop a lighted match into the valve cap opening and immediately insert the carbon burning torch tube with the oxygen valve opened slightly. A too violent stream at the start will put out the match. After the carbon is burning well more gas may be turned on and in the course of a few minutes all the carbon will be consumed, leaving the metal entirely clean. If the opening through which the oxygen is introduced is very large, a quantity of air may be drawn in, reducing the efficiency of the operation, and in this case a means must be provided to overcome this objection. Usually an asbestos disc, with a small hole cut in the center through which the oxygen tube is thrust, is very satisfactory.

It is necessary that there be water in the water jackets of the cylinders, as otherwise the heat of the burning carbon might crack the combustion chamber. After burning the carbon it is a good plan to blow out any loose particles with a jet of compressed air.

By placing the thumb over the exhaust cock of the cylinder while the crank is being turned, the correct position of the piston can be identified very easily. Furthermore, it is possible to decarbonize the engine with one setting of any piston, relying on the position of the crank for setting all pistons after the first.

Considering a four cylinder engine firing in the order 1-3-4-2 it is readily seen from the diagram that during two full revolutions of the crankshaft all four cylinders fire. Therefore, if the piston of any particular cylinder is set at the end of compression the next cylinder in the firing order can be prepared for decarbonizing by turning the crank exactly one-half a revolution. It is safe to



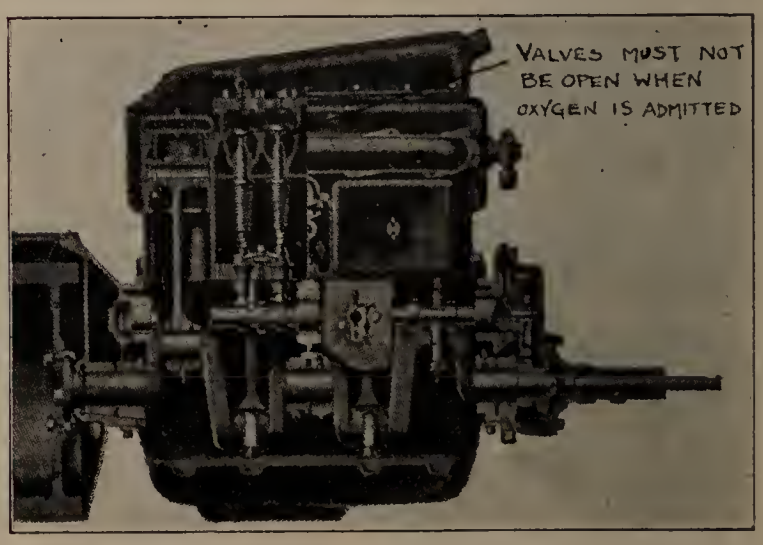
assume that the logical way would be to start with the first cylinder. If, however, the operator should start with any other cylinder, No. 4 for example, the next cylinder would be No. 2 and the complete cycle would be 4-2-1-3. In any case, exactly one-half a revolution of the crank brings the next cylinder into the proper condition for the reaction.

Firing orders of various engines are usually to be found on the engine valve plate unless the plate happens to be so well covered with oil and grease that the numbers cannot be distinguished.

It must be remembered that two complete revolutions are required to complete a cycle for any cylinder, this including admission, compression, firing and exhausting. In the case of a 4-cylinder engine it is necessary to turn the crank one-half a revolution to bring the next cylinder of the engine into the condition requisite for cleaning. For engines of a greater number of cylinders the proper turn for the crank is:

6 cylinder—⅓ revolution
8 cylinder—¼ revolution
12 cylinder—⅙ revolution

Regardless of the thickness or compactness of the deposit, the rate of flow of oxygen can



The Inside of the Cylinder.

be so adjusted that the removal will proceed at a very high rate of speed. Loss of oxygen must be guarded against by the use of port plug bushings, although the opening must

Illustrations as published previously in The Welding Engineer, by courtesy of Lorn Campbell, Jr.

not be so closed that the gaseous products cannot escape.

It is, therefore, safe to assume that the greatest economy can be effected by curtailing all the routine attending the actual injection of oxygen. This not only refers to the procedure of setting the pistons, but also takes in account the removal of spark plugs, wires, and protection of the car.

Carbon Dioxide (CO_2)

A heavy colorless and incombustible gas which results from the perfect combustion of carbon.

Carbon or Graphite Electrode

A cylindrical length of carbon or graphite which is held in a suitable holder connected to the welding circuit so an arc can be formed between the end of the electrode and the part or parts to be welded.

Carbon Electrode Process

See "Bernados" Process and Chapter on "Arc Welding".

Carbon or Graphite Electrode Holder

One form of holder for gripping carbon or graphite electrodes of ½" diameter to 1½" diameter. See chapter on Arc Welding. ing.

"Carbon Putty"

Trade name for a dough-like compound composed of carbon flour and other heat resisting ingredients mixed with water to form a plastic mass. Useful for making molds, dams, etc. May be used a second or third time. Made by Smith's Inventions, Inc., Minneapolis, Minn. See Table of Contents, Catalog Section.

Carbon Monoxide (CO)

A poisonous gas resulting from the combustion of charcoal. Believed to have an adverse effect on the blood. Good ventilation is the remedy. It is an odorless gas.

Carbonizing Flame

The result of unbalanced combustion, caused by insufficient oxygen and excess carbon in the flame. A white cone appears at the tip and beyond the flame there is a white envelope of cooler flame. The

Carbonizing Flame.

streamer is a long blue flame. The excess carbon combines with the molten metal and the metal boils and has a cloudy appearance. The surface of the weld is mottled or pitted and the weld is brittle. See "Neutral Flame," "Oxidizing Flame," and "Flame Chart."

"Carbox"

Trade name for steel rods for acetylene or electric welding. Made by Central Steel & Wire Co., Chicago, Ill. See Table of Contents, Catalog Section.

Case Hardening

It is desirable at times to case harden a piece of steel and very often the average welding shop does not have the required equipment or it may be too much trouble and expense to use it for a small piece. In such a case the welding torch may be used to advantage in the following manner.

Light up the torch, using a tip of the proper size, and regulate the flame to produce a strongly carbonizing flame. Heat the steel with this flame to a point just below melting, playing the white carbonizing acetylene cone on the piece and occasionally turning off the oxygen to cover the steel with carbon or soot, and then cooling quickly in cold water. The carbon is absorbed by the steel while at this high temperature and the depth to which one wishes the hardening process to penetrate determines the length of time necessary to continue the heating. A few minutes application is sufficient to produce a glass hard surface to a very small depth.

It must be understood of course that the piece must be cooled very rapidly as is the case with other case hardening processes.

Present-day Methods of Case Hardening

The most common method of case hardening is to pack steel parts in a metal box filled with carburizing materials and submit the tightly closed box and contents to a sufficiently high temperature for an adequate length of time to obtain the desired depth of case. This process is simple, and assures fair success if properly conducted in accordance with a prescribed procedure, which has been found by experiments to give definite results under specific conditions.

The disadvantages of this process are manifold, some of the more important being: (1) The uncertainty of proper reaction within the closed box. (2) The difficulty in duplicating results as predetermined, because of the non-uniformity of carburizers. (3) The long exposure of the steel to a heat that is not well controlled, which results in a questionable structural condition. (4) The high cost of operation due to the inefficient heating method, the cost of boxes, and their rapid deterioration by oxidation or scaling.

A second method of case hardening is to immerse steel articles in a cyanide bath heated to about 1,580 degrees F. This process is convenient and effective only on small articles and where the required depth is not more than from 0.005 to 0.015 inch, or where a mere surface hardening is wanted. This is a fast case forming method, being accomplished in from ten to fifteen minutes. The outstanding disadvantage of this process is the impossibility of producing uniform cases. The parts that are deep in the melted bath do not receive the same depth of penetration as the parts near the surface because the evolution of the cyanide gases at or near the surface favors penetration. It is hardly feasible to have pots with a sufficient surface area to accommodate the case hardening of a plant.

A third method of case hardening consists of either dipping a cherry-red piece of steel or tool into a container of powdered cyanide salt, such as potassium cyanide, sodium cyanide, or ferro- and ferri-cyanides, or sprinkling the powdered salt on the red-hot steel surface, and putting the steel back in the fire. The case hardening produced in this way is superficial, and resistance to excessive wear cannot be expected.

In a fourth method, the carburizing gases are passed over a piece of steel heated in a retort. This process is applicable to parts that are intricate in design. All the processes referred to serve the needs of the different industries more or less satisfactorily. Box case hardening is dirty and wasteful and sometimes unsatisfactory. Case hardening by firing in fused cyanide salt is inefficient, unreliable, dangerous, and costly. Retort case hardening with carbonaceous gases is a step in the right direction, but it leaves something to be desired on account of the selection of the carbonaceous gases and the method of application.

Casenite

A hydraulically pressed product used for regulator seats. Made from Casein and Formaldehyde.

Cast Iron

See "Cast Iron, Hard Spots In", also chapters on "Oxy-Acetylene Welding," "Electric Arc Welding," "Electric Resistance Welding," and "Thermit Welding." See also "Preheating."

Cast Iron (Hard Spots in Welds)

Very often it happens that a cast iron weld will contain hard spots or will be hard

in places while soft in others. Several things may cause this but the most prevalent reason for it is the chilling of the metal. When molten cast iron is suddenly cooled the dissolved carbon remains in the iron as such but when cooled slowly the carbon separates from the iron in the form of graphite. In the former case a fracture would show white iron and on testing with a file would be found very hard; in the latter case the fracture shows gray iron and is soft. Bearing in mind that suddenly cooling cast iron chills it and makes it hard, think what happens when a cold welding rod is plunged into the pool of molten metal under the flame in a welding operation. The rod being cold, chills the metal it comes in contact with and results in the small round hard spots so irritating to a machinist in finishing a weld. To overcome this trouble, heat the rod to redness before bringing it in contact with the melted iron. Then take the case of welding a tooth or a boss on a gear wheel or other large casting—if the casting is cold and the filler rod is added the metal cools immediately on being welded to the casting and results in a hard chilled weld, lacking strength and impossible to machine.

again being bothered with them to his disgust and sometimes dismay.

This article is written in the belief that, if the real cause of hard spots is thoroughly understood, any welder, by using a little common sense, can at all times avoid them, or if, as may occasionally be the case, this is not possible, he may know what to expect and notify his customer accordingly, so there will be no misunderstanding, or hard feelings.

To begin with, we all know that a piece of tool steel, such as a cold chisel, may have the cutting edge hardened by heating it red hot and plunging in water, also that it may be tempered or made somewhat softer and less brittle, by warming up to less than a red heat, and allowing it to cool, either in air or by again quenching it. We also know that a piece of wrought iron cannot be so hardened. Again, we have become aware by experience that a chisel that has been hardened, may again be softened by heating to a red heat and cooling slowly, and that the slower the cooling, the **softer** it will be when cold. So that:

First: It is evident that there is some relation between the rate of cooling and the hardness of the steel, because this is

Fig. 1. Longitudinal section of wrought iron welding wire. The black streaks and spots are slag. The grains are outlined by the dark lines, and are nearly pure ferrite. 200X.

Fig. 2. Boiler plate containing about .18% carbon. The ferrite grains are clearly outlined by the dark lines, but the dark spots at the grain boundaries are pearlite, and contain all the carbon in the steel. 200X.

Fig. 3. Same as Fig. 2, but at higher power. 750X. The pearlite spots show their laminated structure. The etching was not sufficient to show the grain boundaries. The rather rapid cooling of the plate has prevented the full development of the pearlite. 750X.

Fig. 4. Annealed .45% carbon steel. Ferrite at grain boundaries (F); pearlite in center of grains. The amount of ferrite becomes less, and the pearlite more as the carbon increases. 200X.

Fig. 5. Steel containing about .77% carbon; it is nearly all pearlite. The light plates are cementite, the dark ones, ferrite. The dark color of the ferrite is due to light and shadow effects; they are really nearly as white as the cementite. 1200X.

Fig. 6. Annealed 1.1% carbon tool steel. Pearlite grains surrounded by cementite films; there being more carbon than necessary to make pearlite, the excess appears around the grain boundaries. 1200X.

Fig. 7. 1.1% carbon tool steel quenched in ice water from 1800° F. The white plates or needles are martensite; the dark parts show that the cooling was not rapid enough to hold all the metal in the martensitic condition. 430X.

Fig. 8. .18% carbon steel quenched from 2200° F. in ice water. The structure is the same as with high carbon steel, but the low carbon permits the piece to be machined while the piece in Fig. 7 cannot be. 200X.

Fig. 9. Very soft cast iron. Ferrite grain boundaries show clearly. There is no pearlite. The large dark parts are graphite. 200X.

Fig. 10. Cast iron of Fig. 9 quenched from 1800° F. in ice water. Some of the graphite plates (dark streaks and spots) still remain, but the ground mass is martensite, as in Fig. 7. 200X. (The white spots contain the phosphorus in the metal, and are a eutectic of Iron carbide, iron and Iron phosphide, commonly called phosphide eutectic.)

Fig. 11. Same as Fig. 10, but showing the martensite more clearly at higher power. 430X.

Fig. 12. Cast iron of Fig. 9 heated to 1800° F. and cooled in furnace. This would be the structure of an ordinary casting. The grains are all pearlite. The black plate is graphite. (The white banded and dotted part is well developed phosphide eutectic.) 430X.

The use of a poor flux or the use of an excessive quantity, will produce hard welds, impurities in the filler rod or rods low in silicon also result in hard porous welds.

Writing for **The Welding Engineer** Mr. S. W. Miller said:

Much has been written in **The Welding Engineer** and other papers regarding the so-called "hard spots" in cast iron welds, and their cause has been many times explained correctly. The matter bobs up serenely, however, from time to time, and it would seem advisable to go into more detail in regard to them than has hitherto been done, as far as the author knows.

To do this will require considerable explanation of details, and some patience and study on the part of the average welder, who, by force of circumstances and through no fault of his own, is not acquainted with some of the elementary facts in regard to the structure of iron and steel, and, therefore, doing the best he knows how, stumbles along, sometimes having no hard spots and

the only difference in the treatment, and we deduce that **rapid cooling** is the cause of the steel hardening, and that **slow cooling** makes it soft.

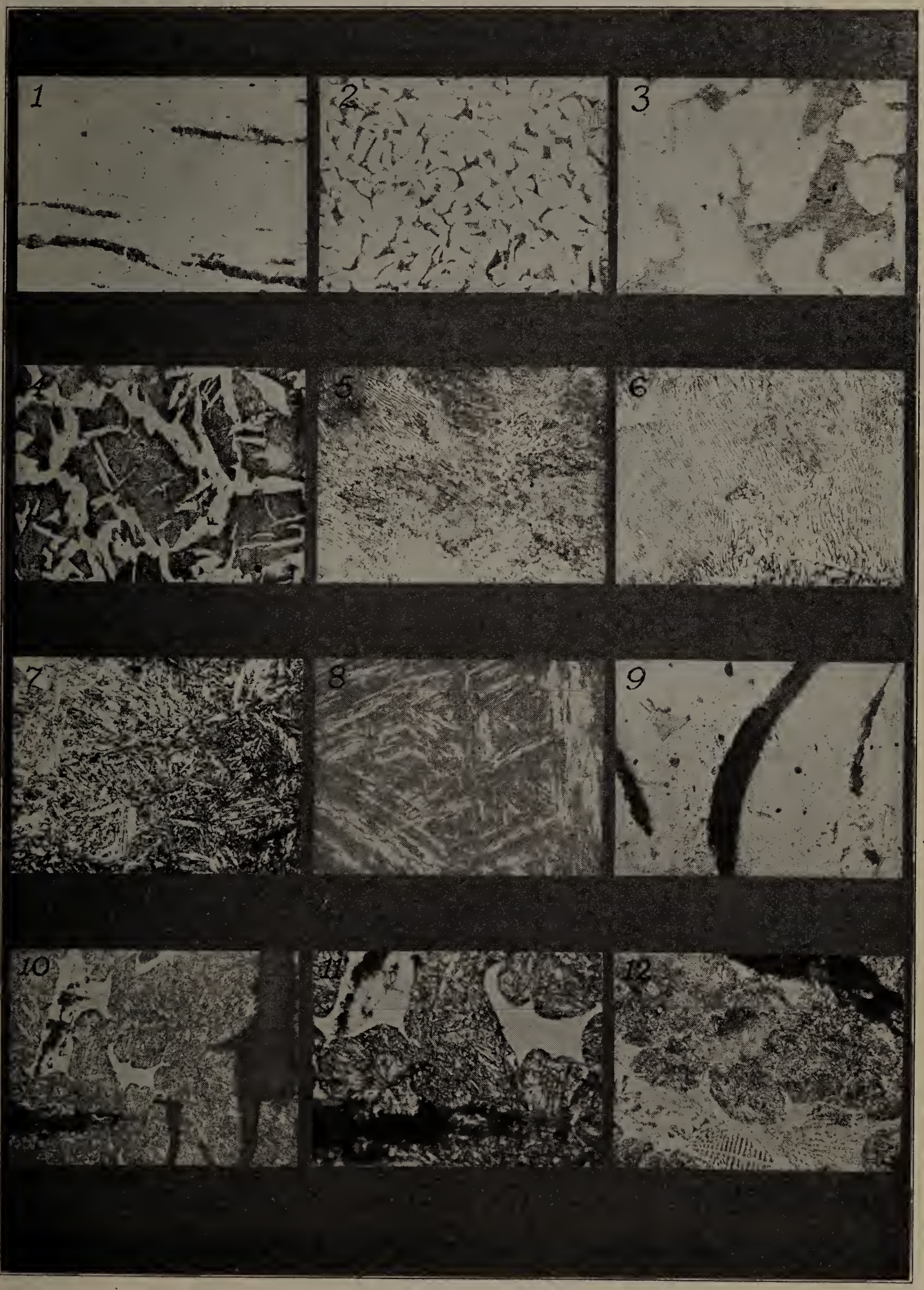
Second: As wrought iron cannot be hardened by quenching from a red heat, we deduce that there must be some difference between the two metals, and that tool steel must contain something that wrought iron does not, which enables it to be made hard by quenching.

Both of these deductions are correct. In the latter case, the chemist finds that tool steel contains carbon, and that wrought iron does not, and that if enough carbon is added to wrought iron, it becomes tool steel. In the former case, we readily convince ourselves, by repeated trials, that our idea is correct.

Taking a further step, we ask the chemist to analyze a piece of hardened tool steel, and a piece of the same steel unhardened. He advises us that each contains the same amount of carbon and other elements, and

we wonder how it can be true. Certainly the two pieces of steel have widely different physical properties; the former is very strong, very hard and very brittle; while the latter can be easily filed or machined, is quite ductile, and not nearly so strong.

for the facts. It is not the intention of the author to trace the various steps made by the pioneers in this work, but he does desire (and it is necessary to a correct understanding of hard steel) to begin at the bottom and explain the terms and principles



(See Opposite Page for Description of Above Microphotographs.)

Thinking the matter over, the only thing we can see is that some physical change must occur on account of the quenching, as there is no other supposition that will account that are involved.

The microscope has proven the best means of determining the physical changes occurring in metals due to different heat treat-

ments, and we will make liberal use of its powers of analysis. The following statements will be accepted as true, having been proven by competent investigators and accepted by nearly all metallurgists:

First: Carbon does not exist in steel as carbon, but as a chemical compound, carbide of iron[1], which is dissolved in the iron of the steel at high temperatures, but which will not stay dissolved when the temperature falls below about 1,300 degrees F.

Second: In cold steel the carbide of iron exists under normal conditions mechanically mixed with some of the iron. Both are in the shape of thin plates, arranged alternately, sometimes straight, and sometimes curved. Many times this mechanical fixture takes on the appearance of the whorls on the finger tips.

Third. The iron in steel is called ferrite, to distinguish it from the usual terms "iron" or "steel," which include the whole mass; that is, ferrite is only one of the structural constituents of "iron" or "steel," which are not all ferrite.

Fourth: So that the mechanical mixture of iron and carbide of iron is usually described as alternate plates of cementite and ferrite, and for a short name "pearlite" has been adopted, as under reflected light it has a luster like mother of pearl. These plates are very thin, less than 1/25,000 of an inch.[1]

So far we have to remember, therefore, the three terms, cementite, ferrite, and pearlite, surely not a very hard task.

Fifth: The essential difference between steel and cast iron is that cast iron contains more carbon than steel. Commercial steel and cast iron both contain other elements, such as silicon, manganese, sulphur and phosphorus, and their presence or absence affects the quality of the steel or cast iron materially. But carbon exerts the greatest influence, and is, in fact, the element necessary for hardening steel.

Sixth: We may make a series of alloys of any two metals or elements, the amounts of each metal varying, but the sum of the two amounts being constant. For example, we may use 90 per cent copper and ten per cent tin, or 50 per cent copper and 50 per cent tin, or ten per cent copper and 90 per cent tin. Some of these will be of no value practically, but they can be made. It is also evident that some one of these alloys will have a lower melting point than any of the others. This alloy is called the "eutectic" alloy of the series, from the Greek words meaning well melting. (There are a few series of alloys in which there are no eutectics, but the above explanation is sufficient for our purpose, and is generally true.)

The structure of a eutectic is usually banded, resembling pearlite. Sometimes it is in the shape of round or elongated globules in the ground mass. The term eutectoid, which means resembling a eutectic, is used to describe a structure resembling in appearance a eutectic, but which is not an alloy of the lowest melting point, as it does not form when the metal solidifies from fusion, but sometimes afterward. Pearlite shows such a structure, and as it is not a eutectic, the term eutectoid is applicable to it. We now have five terms to remember, which are all that are needed for the purpose.

They are: Ferrite, cementite, pearlite, eutectic and eutectoid.

As pure iron is the basis both of steel and cast iron, we will see what it looks like under the microscope and then determine what differences are made by the addition of carbon and other elements.

Photo No. 1 shows fairly pure wrought iron welding wire. The black streaks and specks are slag. It will be noticed that the metal is composed of a large number of different sized grains, the boundaries showing dark and continuous, and the grains almost uniformly bright and clear. The grains are ferrite, practically pure. The boundaries are really shadows thrown by the edges of the grains, the surfaces of which are not all of the same height, owing to the action of the etching acid not being the same on each grain.

Photo No. 2 is of a piece of boiler plate,

[1](*Carbide of iron is a chemical compound just as is calcium carbide, with which every welder is familiar. The chemical formula of iron carbide is Fe_3C, meaning three parts of iron (Fe) and one part of carbon (C) by weight. Calcium carbide is represented by the formula CaC_2, meaning one part of calcium (Ca) and two parts of carbon (C) by weight. The technical name of carbide of iron is cementite. It is the hardest component of steel; it will scratch glass, and is also very brittle. It is brilliant white after etching, and after polishing projects above the rest of the surface. The carbon in the carbide of iron is the same chemically as the material of which an electric carbon, or the lead in a pencil is made.*)

Fig. 13. Cast iron welding rod as received. The white is ferrite, the dark is very fine pearlite. The dark plates in the ferrite are graphite. The half tone spots in the pearlite are phosphide eutectic. The etching is deep enough to show the grain boundaries in the ferrite. 430X.

Fig. 14. Same rod as Fig. 13 heated to 1800° F., and cooled in furnace to resemble an ordinary casting. Mostly ferrite and graphite. One pearlite spot. The slow cooling has made much more graphite and ferrite than in Fig. 13. 430X.

Fig. 15. Same rod as in Fig. 13 melted and quenched in ice water. Even with this rapid cooling there is much graphite present, because of the large amount of silicon. The whitish ground mass is mostly martensite. The irregularly shaped white spots are probably phosphide eutectic (not well developed), and cementite. 430X.

Fig. 16. Same as Fig. 15, but at higher power. 1200X. The martensitic structure is very clear. This piece is glass hard. Compare with Figs. 7, 10 and 11. 1200X.

Fig. 17. Same rod as in Fig. 13 heated to 1800° F. quenched in ice water. The structure is about the same as in Fig. 15, but there is more graphite, because of the lower quenching temperature. 430X.

Fig. 18. Section through spot on piece of cast iron, heated just to melting point and allowed to cool in air. The quenching by the cold iron around the melted spot was very rapid. The white layer (W) on top, has had some of the silicon burned out, and the rapid cooling has made white, or chilled, iron. 3X.

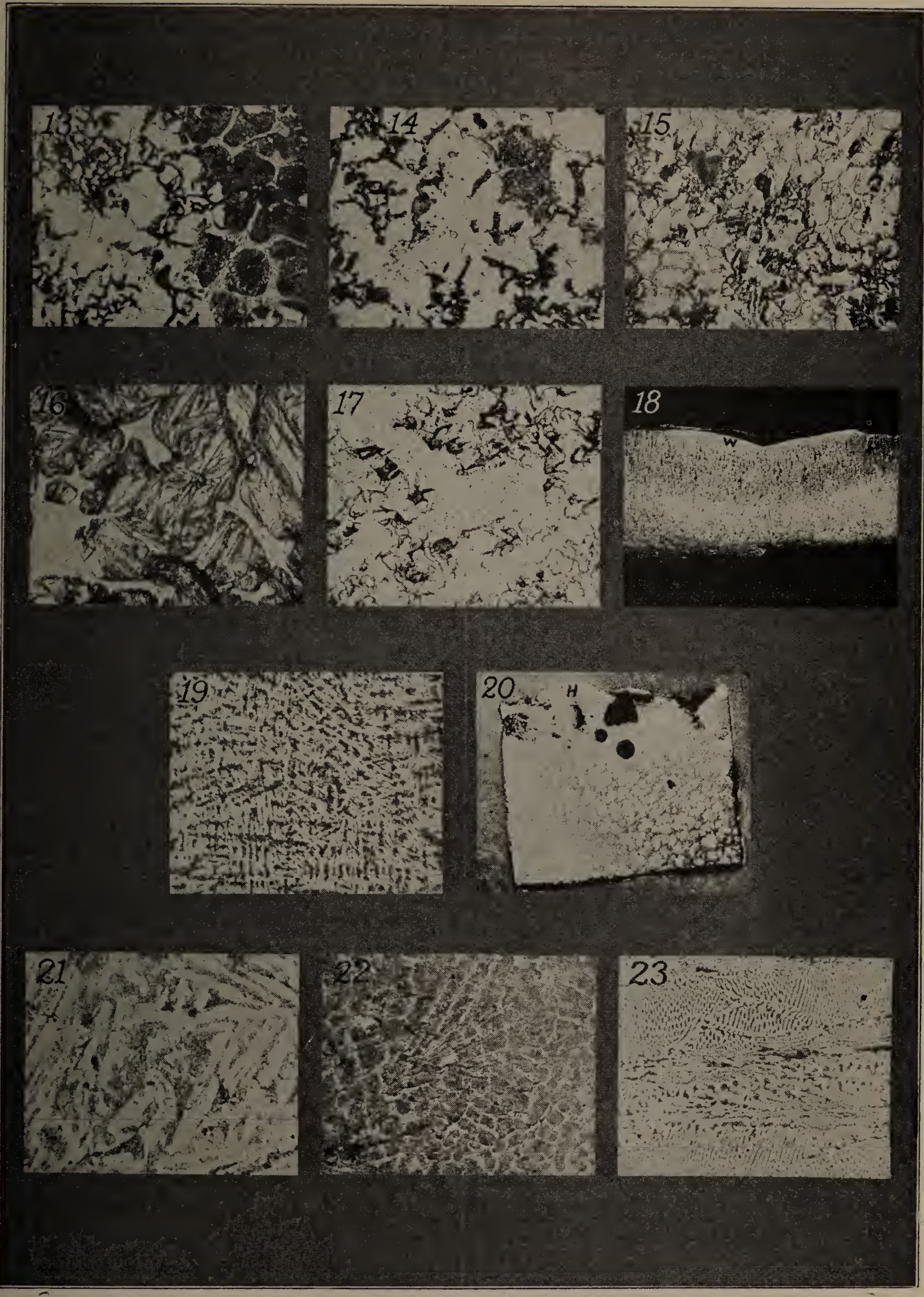
Fig. 19. Structure of white layer of Fig. 18. The white is cementite, and the dark, pearlite. 430X.

Fig. 20. Hard spot, H, in a weld. This is in the original metal. 4X.

Fig. 21. Structure of hard spot in Fig. 20. It is the same, cementite (white), and pearlite (gray), as in Fig. 19, but coarser because of the longer application of the heat. 430X.

Fig. 22. Chilled cast iron. The white is cementite and the ground mass, gray, is pearlite. 100X.

Fig. 23. Eutectic of iron and carbon. 4.3% carbon. The white is cementite, the dark is pearlite. Notice the banded and dotted structure, which is similar to that of the phosphide eutectic in Fig. 12; also, its partial resemblance to pearlite, Fig. 6. 200X.



(See Opposite Page for Description of Above Microphotographs.)

containing about .18 per cent carbon. The only difference[2] between this and Photo No. 1 is that in the No. 2 there are some dark irregular shaped patches between the corners of the grains. Under high magnification, as in Photo No. 3, the structure of these dark spots shows duplex, consisting of alternate light and dark plates. This duplex structure is pearlite as before explained.

If we examine ordinary machine steel, such as we purchase at an iron store, or a piece of structural steel, such as an I beam, either of which contains, say, .3 per cent carbon, we find still more of the pearlite. The amount still further increases as the carbon increases, as shown in Photo No. 4, from a piece of shell steel, containing about .45 per cent carbon, and

[2] *The difference in the size of the grains in the two photos is due to different heat treatments, and does not affect the accuracy of the statement.*

Photo No. 5, from a locomotive tire, containing about .77 per cent carbon. It will be noticed that No. 5 is composed almost entirely of pearlite, there being very little free ferrite, that is, ferrite other than that in the pearlite. It has been found that a pure iron-carbon alloy of about .9 per cent carbon is composed entirely of pearlite and it is, therefore, called eutectoid steel, pearlite being the eutectoid of iron and carbon.

In Photo No. 6, from a piece of tool steel containing about 1.1 per cent carbon, we see a structure that somewhat resembles that of Photo No. 5, but with the difference that there is white material around the grains. Tests prove that this white material is cementite and it is called free or excess cementite to distinguish it from the cementite in the pearlite, there being more of it than just enough to make the structure all pearlite.

Let us now consider the changes that occur when steel is hardened. It is stated above that the iron, when at high temperature, has dissolved in it the carbon, in the form of carbide of iron. It must be understood that the iron does not have to be melted to do this. The familiar idea of a solution is a solid dissolved in a liquid; for example, salt and water. But in the case of metals, we must extend our ideas to take in the fact that one solid can dissolve another. The case hardening of iron, and the making of tool steel by the cementation process are well known examples of the dissolving of carbon in steel while red hot, but not melted. Such a solution is called a solid solution for obvious reasons. An excess acetylene flame played for some time on a piece of iron will put enough carbon into it to make tool steel of its outside surface. As the carbide of iron is not held in solution in cold iron, there must be some temperature below which it exists as carbide of iron. This temperature is about 1,300 degrees F. The change from the solid solution occurs in a 1 per cent carbon steel as follows: As the steel cools from the melting point, it solidifies by degrees through quite a range of temperature, say from about 2,660 to 2,180 degrees F.; at the latter temperature it is entirely solid, and is a solid solution of carbide of iron in iron. No further change takes place except that it becomes cooler as the temperature falls further, till 1,480 degrees F. is reached, when the excess cementite before mentioned falls out of solution, and the steel consists of a mass of grains of solid solution surrounded by films of cementite. When the temperature falls to about 1,300 degrees F., the grains of solid solution change into pearlite, and the structure is as shown in Photo No. 6. No further change occurs as the metal cools down to the ordinary temperature. The changes and temperatures given are correct only for 1 per cent carbon steel, but give an idea of what happens in all steels.

If we desire to see the structure of any steel at a high temperature, we may do so approximately by heating it to that point, and quenching it as suddenly as possible by plunging in ice water. The structure resulting is only approximate because it takes an appreciable time, even with liquid air, to cool the specimen, and during that time some change is occurring; still we gain much from such a procedure.

Photo No. 7 shows a piece of the same steel as in Photo No. 6, quenched in ice water from 1,800 degrees F. It shows what is called martensite, and is the structure of all quenched steels. Photo No. 8 shows a piece of soft steel quenched from 2,200 degrees F. in ice water. The structure is the same, but there is very little hardness to it, and it is easily machined, while the former piece (Photo No. 7) cannot be machined at all.

As stated before, the greatest difference between commercial steel and cast iron is that the former does not contain over about 1.5 per cent carbon, while the latter may contain from 2.25 to 4 per cent, while all the carbon in steel is in the shape of carbide of iron, in ordinary cast iron some of it is in the shape of graphite, which is just the same material as the black lead used in making pencils and crucibles. This soft friable material imparts its qualities more or less, in proportion to its quantity, to the cast iron, so that cast iron is softer and weaker than steel. This graphite is frequently called graphite or free carbon to distinguish it from the carbon existing in carbide of iron, which for obvious reasons may be, and sometimes is, called combined carbon.[3]

The action of other elements in cast iron, such as manganese, sulphur, phosphorus and silicon, is quite complicated; but one fact stands out clearly and that is that as silicon is increased, other things being equal, the iron becomes softer, because silicon promotes the formation of graphite, and of course prevents the formation of pearlite, this making the iron soft. As cast iron is an iron carbon alloy, just as is steel, it would naturally be expected that the rapidity of its cooling would have about the same effect on it as on steel, and this is the fact. Every foundry man knows that a small casting poured from the same ladle as a large one will be closer grained, harder, and stronger than the larger one. This is on account of the more rapid cooling in the case of the small casting. And as he also knows that silicon is a softener, he uses, or should use, less silicon in his large castings than in his small ones, if he desires the same quality of iron in both cases. Photo No. 9 shows a very soft piece of cast iron. Notice the large graphite plates, and the large proportion of the space they occupy; also the absence of pearlite. It is from a large casting and apparently the iron is high in silicon, and evidently was cooled slowly, allowing the full development of the graphite. Notice also that, aside from the graphite, the structure is the same as in Photo No. 1; that is, irregular grains with nothing between them.

Photo No. 10 shows the same iron heated to 1,800 degrees F. and quenched in ice water.

Photo No. 11 shows the same field at higher power; it resembles Photo No. 7.

Photo No. 12 shows the same iron heated to 1,800 degrees F. and cooled down with the furnace, which produces a structure similar to that of an average casting from the metal. This shows that very slow cooling was the cause of the large amount of graphite in Photo No. 9, and that the silicon is not unusually high.

Photo No. 13 is from a piece of welding rod. This is high silicon material, and as it is cast in small rods, it is rapidly cooled, and the structure is different from Photo No. 9.

Photo No. 14 is a piece of the same rod heated to 1,800 degrees F. and cooled in the furnace to resemble somewhat the cooling of an average casting.

Photos No. 15 and 16 are from a piece of the same rod melted and quenched in ice water.

Photo No. 17 is from the same rod heated to 1,800 degrees F. and quenched in ice water. It is so hard it cannot be filed.

Photo No. 18 shows a spot on the face of a piece of ordinary cast iron just melted with the torch and chilled by radiation and conduction. The photo is a section through the center of the spot, and the white edge is shown in Photo No. 19. It consists of cementite, the white material, and pearlite, the darker parts. It is of course too hard to machine or file.

Photo No. 20 shows a hard spot in a weld,

[3] *That is, combined chemically with iron, as carbide of iron.*

a section having been made through it, while the structure is as in Photo No. 21. It is the same, though a little coarser, as in Photo No. 19. The hard spot is in the original material.

Photo No. 22 shows a piece of chilled iron, which has the same structure as the hard spots. The difference between the various pieces of cast iron shown above is in the rapidity with which the quenching has been done. Ordinary chilled iron is cooled no faster than any other sand casting, but in all cases of hard spots in chilled iron, the rate of cooling is about the same, and much less than that of the quenched pieces of cast iron shown so that there is time for the cementite to separate out as such instead of being partly held in solid solution and appearing as martensite, as in the quenched pieces of cast iron and steel. It therefore appears that the structure of either piece of cast iron or steel depends with a given chemical composition upon the rapidity of cooling and the temperature from which it is cooled. The former is the more important of the two.

It should be noticed that the structures of both cast iron and steel are the same with the same heat treatment, that is, the same quenching treatments, with the exception of the size of the grains. The grain size is dependent upon a great many considerations, a discussion of which is not necessary at the present time, but in the cast iron will be found ferrite and pearlite as in steel, and if the graphite could be removed from the cast iron, and these spaces welded up, we would have steel; and so it is natural that heat treatment would have the same effect on the two metals. During the welding process, it is never possible to secure severe enough quenching to produce martensite; but the cooling is rapid enough at times to produce chilled iron, as is clearly shown in the photographs. It is quite clear from the photographs that even with a very high percentage of silicon, sufficient hard material, such as martensite or cementite, can be produced to make the metal hard. Silicon is quite readily burned out, and with its removal, the chilling properties of the metal are increased so that hard spots are caused by the rapid cooling of the metal aggravated by the removal of silicon by heating. Table No. 1 shows the average compostion of ordinary machinery cast iron, of cast iron welding rod, and of chilled cast iron. The two important elements are the carbon and silicon. The carbon is the same in all three cases, while the silicon is lowest in the chilled iron and highest in the welding rod. The large amount of silicon in the welding rod permits of some of it being burned out, and also of rather rapid cooling before the weld will become unmachineable, but in the case of machinery iron, the amount will not prevent hard spots, because some of it will be burned out, and because the original material is not brought to so high a temperature as the weld, so that its cooling is more rapid than that of the weld. For these reasons, hard spots are usually in the original material and not in the weld.

The remedy for, or rather the avoidance of, hard spots is simple. The weld material should be piled up a trifle above the edge of the V and the original material melted together with the added material, and the two allowed to run together. This not only increases the temperature of the original metal next the V, but allows some of the silicon from the weld to pass into the melted original, thus keeping it soft. The fact that silicon is rather easily burned out of cast iron also shows the necessity of not keeping the heat on it during welding any more than is necessary.

These conditions all being within the control of the one doing the welding, it is, as one of the correspondents of **The Welding Engineer** has truly said, "entirely up to the welder."

It may be of interest to note in Fig. 23 the eutectic alloy of iron and carbon which contains 4.3 per cent carbon, and which melts at 2,075 degrees F., while pure iron melts at 2,730 degrees F.

TABLE NO. 1

	Machinery Iron Per Cent	Welding Rod Per Cent	Chilled Iron Per Cent
Elements			
Carbon	3.50	3.50	3.50
Manganese	.80	.50	1.00
Sulphur	.09	.05	.05
Phosphorus	.60	1.00	.18
Silicon	2.00	3.25	.90

"Castox"

Trade name for welding rod for acetylene welding of cast iron. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Castweld"

Trade name for filler rod for cast iron welding. Made by Steel Sales Corporation, Jefferson and Adams Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Cathode

The negative electrode of an electrolytic generator on which the hydrogen gas collects.

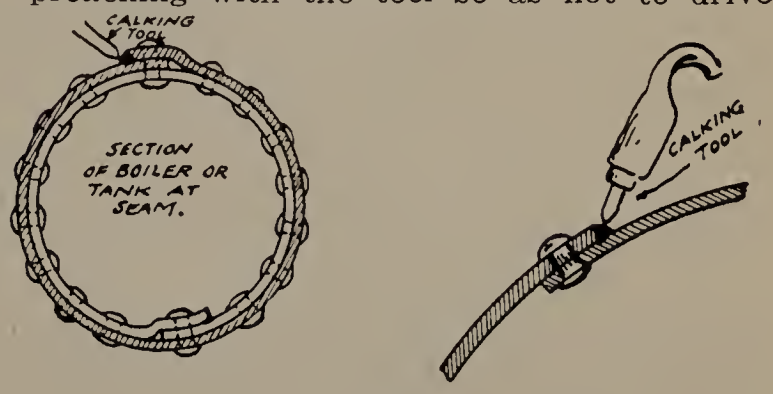
Caulking

Flowing the welded metal into a more compact mass by light hammering with a rounded tool, usually an air hammer.

The illustration shows an apparently easy job to the uninitiated, that is the welding of a caulking edge on a boiler or tank. This job is far from being easy, however, because in most cases the welder is called to fix up a leaky seam and the cause of a leaky seam is movement of the plates or rivets. Simply running a caulking edge along the joint will in general make the seam tight when not in use, but upon the boiler tank being put in service, especially under pressure, the plates are liable to assume a different shape or position under load than when quiet, the strain then being entirely brought upon the weld whereat it is broken or pulled away, adequate provision not having been provided to equal the strength of the plates to which it is welded.

It is not always the correct thing to do to make this weld stronger than the plate. In a boiler, for instance, where rivets have been installed for part of the seam, it is best to fire up the boiler and put it under full pressure, thus straining it into its final position before welding.

How a caulking seam should be made, approaching with the tool so as not to drive



Caulking

the weld under the plate, is shown at the right of the illustration. A great deal of experience is needed in caulking for arc welding just as caulking experience is needed for rivet work. Every boiler maker knows that an amateur will do with a caulking tool more harm than good and similarly in welding; too much caulking is

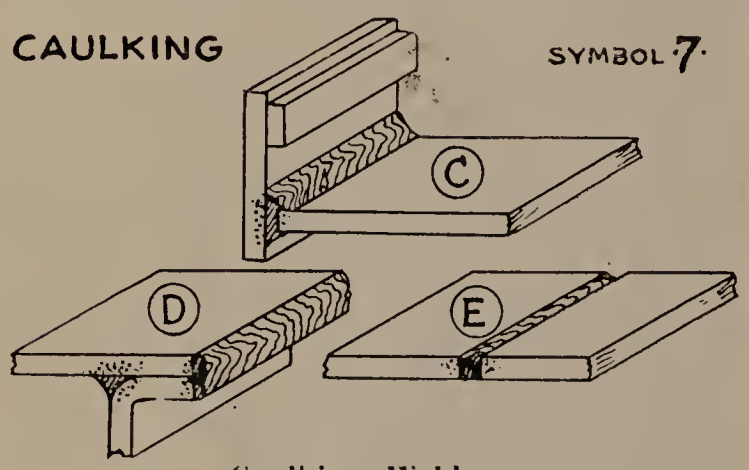
harmful instead of beneficial. A multiplicity of light rapid blows is the only reliable caulking method on a weld, whether the caulking is for a smooth finish or to make the surface denser against warping. Also, too much caulking will cause the surface of the weld to crumble and repeated caulking of this nature will finally result in crumbling the welding all away.

Caulking rough looking welds for a finish is common practice, but in this case the rougher part of the weld must be chipped or ground approximately the size before caulking, or the efficiency of the weld will be much lowered, both as to strength and tightness. Working a weld cold exeept on the surface would be similar to working a sheet cold of similar dimensions which could be easily cracked or ruined. Working the weld hot is a different matter, but it is almost impossible to caulk metal arc welding while hot, although in many instances on very careful work each inch or two is caulked while hot (just after it is put down) with a ball peen hammer in the hands of the welder.

In very few instances the weld can be reheated and caulked but these are very scarce as reheating would in general cause more strain and stresses than would be relieved by caulking. See "Boiler Welding."

Caulking Weld

A Caulking weld is one in which the density of the crystalline metal, used to close



Caulking Weld.

up the seam or opening, is such, that no possible leakage is visible under a water, oil or air pressure of 25 lbs. per square inch. The ultimate strength of a caulking weld is not of material importance—neither is the "Design of Weld" of this kind necessary of consideration. The operator must be the judge in the number of layers needed for a tight weld, although the designer should specify a minimum amount of layers.

Cell

A unit of an Electrolytic Oxygen and Hydrogen generating plant. The size and capacity of such plants may be increased by the addition of additional cells.

Cementite

See "Cast Iron, Hard Spots in Welds."

Center Pour Weld

A modified type of the Thermit Insert Rail Weld. See chapter on "Thermit Welding."

Centigrade

Scale for measuring temperatures, the range being from zero, the freezing point of water, to 100°, the boiling point of water. If F be the given temperature in Fahrenheit degrees and C the corresponding temperature in Centigrade degrees the former may be converted into the latter by means of the equation: $(F - 32)\ 5/9 = C$, and conversely. Centigrade degrees may be converted into Fahrenheit by means of the equation: $9/5\ C + 32 = F$.

"Cesco"

Trade name for goggles. Made by Chicago Eye Shield Co., Chicago, Ill. See Table of Contents, Catalog Section.

Chamfer

See "Bevel."

Channel

Opening made by beveling or chipping between parts to be welded.

Chassis Welds

An automobile frame is almost always either a channel or an I-beam. The strength of a beam of any section depends on its moment of inertia. The reason for making I-beams and channels is because the distribution of a certain amount of material in either shape gives a greater strength than when it is in the form of a flat plate or rectangular beam. It is also true that the deeper the beam for a given weight, the stronger it is. The moments of inertia of three shapes weighing 15 lbs. to the foot of length are given herewith:

6 in. I-beam	24
6 in. channel	19 5
10 in. channel	66.9
Flat plate on edge 6 in. deep, 7/10 in. thick	12.6

It is evident that the flat plate is by far the weakest. The strengh of an I-beam and channel is made up of the strength of the web and the flanges. In the case of the 6 in. channel, the moments of inertia are:

Web	6
Flanges	13.5

The weight of the web is about 40 per cent of the total weight of the section, and this 40 per cent gives less than ⅓ of the strength of the channel. This shows that if we want to increase the strength of a channel section, we can do so much more easily by adding metal to the flanges than we can by adding metal to the web, so that for the greatest economy of time and material, the reinforcing of a broken automobile frame should be done by welding a piece on the bottom flange which is where they usually break. This can be placed either on the inside or outside as may be best, but the outside is usually the easiest to get at.

The thickness of the reinforcement may be about three-sixteenths inch on an ordinary touring car frame and from ¼ inch up for truck frames, depending on their size. It should be welded all around the edge after the break in the frame is welded.

The break in the frame should be welded on both sides. Care should be taken, however, not to use any larger tip or any greater current than is necessary to make a sound weld.

One method of welding a broken gooseneck of an auto by the electric arc process is shown in Fig. 1. When using this method it is not necessary to remove the radiator or gas tank and very few parts, only enough to

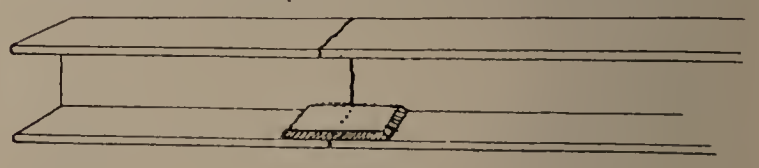


Fig. 1.

give access to broken parts and never damage paint on body, regardless where the break or damage is on the frame, because no flame spreads to adjacent parts. First, align the broken parts and weld crack, then place small reinforcing patch on bottomlip and weld it in place.

Fig 2 illustrates a method of welding truck frames, bringing broken parts to proper alignment and cutting out a space with the acetylene torch and welding same, placing a patch on the inside (a channel within the frame), and welding it in place.

Frequently the frame is so fractured, that in order to make an oxy-acetylene weld the car must be partly dismantled. When the weld is in the neighborhood of the radiator it is advisable to remove the radiator entirely to prevent melting out the solder.

Likewise, work in the neighborhood of the gasoline tank should never be undertaken unless the gasoline tank is removed. Even when the weld is to be performed at a distance from the radiator or gasoline tank it is safer to protect these parts with sheet asbestos. If the break is near the carburetor, it should be drained. All oil soaked parts of the machine should be protected with sheet asbestos. "Safety first" should be the foremost consideration, even though its observance entails a slight expense or additional trouble. The prevention of possible damage and the elimination of fire and explosion hazards are well worth it.

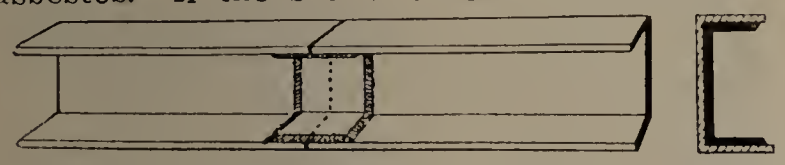


Fig. 2.

The customary method of handling a fracture (illustrated in Fig. 3) consists in aligning the broken members. The frame is jacked into position with the fractured cross-sections exactly in their relative positions. The surfaces adjacent to the break must be thoroughly cleaned. All dirt, paint, oil, and rust must be removed. It is possible to do this most effectively by applying the torch flame and scraping with a flat-edged tool.

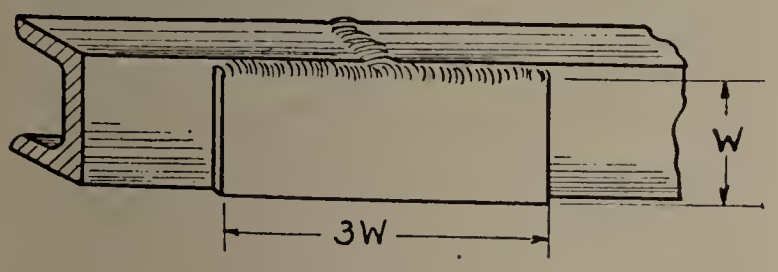


Fig. 3.

The fracture is then welded according to the procedure generally followed in the case of any steel weld made with the oxy-acetylene process. A pure iron filler rod (Norway iron) should be used and should be added to the break starting at the bottom flange of the channel, then vertically upward, and finally along the top flange. This means one overhead, one vertical, and one horizontal weld, but there is nothing exceptionally difficult in any one of the three and any skilled welder should be able to execute them. It is, however, of utmost importance that the vertical weld be started at the bottom and that the weld be executed upwards. This eliminates any incorporation of gases in the weld as would be possible were the reverse method followed. A perfectly neutral flame must be maintained. Even a slight deviation from the neutral composition will affect the soundness of the weld by either carbonizing or oxidizing it. Hammering the weld materially improves it and is advisable.

A weld finished as above described can be made as strong or even stronger than the original material by adding to the cross-sectional area. Although permissible and to some extent utilized this practice is not generally followed and it is deemed safer to reinforce the weld by tacking a plate across the welded joint. This plate should be of the same thickness as the channel frame and about three times as long as it is wide.

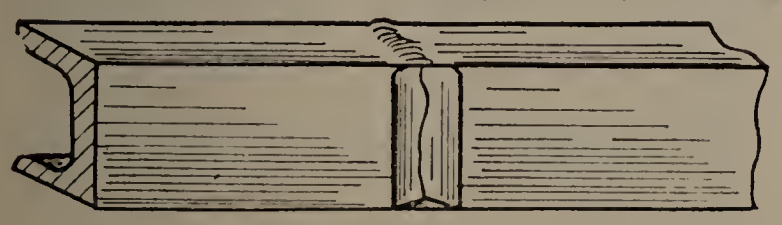


Fig. 4.

The width of the plate is governed by the depth of the channel. Usually it is welded to the inside of the frame but occasionally the fracture occurs at a point where a cross-member is riveted to the channel and this necessitates welding the plate on the outside. The horizontal welds are made first and the vertical welds last, these being executed in an upward direction. Sometimes the reinforcing plate is made in the shape of a channel section which just fits inside the automobile frame. Although this construction is very neat in appearance it does not materially aid so far as strength is concerned. A flat plate is enough to make the repaired section far stronger than any other part of the frame.

Another procedure shown in Fig. 4, consists in jacking up the frame, aligning and cleaning the break and adjacent surfaces. The top and bottom flanges of the channel are then welded and slightly reinforced by means of additional filler rod. The channel sections adjoining the break are then heated with the torch to a dull red and hammered in, to form a "V" shaped depression of very obtuse form. The "V" is generally started about one inch to either side of the break and is made about ⅜-inch deep. The vertical weld is then made as though the two pieces were heavy steel plates beveled and prepared for a vertical weld. Or better still, assume that the channel is a broken casting with a fracture which has been beveled out leaving a depression 2 inches wide and ⅜-inch deep. Using Norway iron filler rod and beginning at the lowest point, steel is added to the frame layer upon layer until the "V" is completely filled. It is essential that the rod be properly fused and so incorporated that the layers lap and form perfect unions. The surface is smoothed down with the flame and can be filed flat after cooling.

This method produces a column of much stronger section than at any other point of the chassis frame and one that will outlast the machine itself. It eliminates the use of steel plates. Furthermore, it leaves a smoothly finished exterior (which is not always possible by any other method), a very important consideration in the case of pleasure cars, where appearance counts.

Too much cannot be said about carefulness in executing chassis frame welds. In the case of trucks the body is generally removed and the job completed without any difficulties. On the other hand pleasure cars are prone to offer many difficulties. It does not take much heat to scorch the enamel off the body and the owner surely has a right to look askance at the welder after such an occurrence. Other damage can easily be produced by carelessness.

The use of powdered asbestos well soaked with water is a very useful aid in protecting parts adjacent to those being welded. There should be no skimping on the part of the welder in applying this material as it may be the means of saving himself much trouble and expense.

Chipping

To Bevel or remove metal on the welding line. See "Bevel."

Chromium

A metallic element sometimes added to steel to give increased toughness and hardness.

Any material which has chromium in it welds with difficulty because of the formation of chromium oxide which makes an ugly coating on the surface. This cannot be removed by any flux, but the welding can be helped by using borax or boracic acid. Care must be taken not to stir up the metal by rubbing the rod around in the weld. If this precaution be taken and the metal melted underneath the coating of oxide quite good results can be obtained although the welding is slower than with ordinary steel.

"Clean-Al"

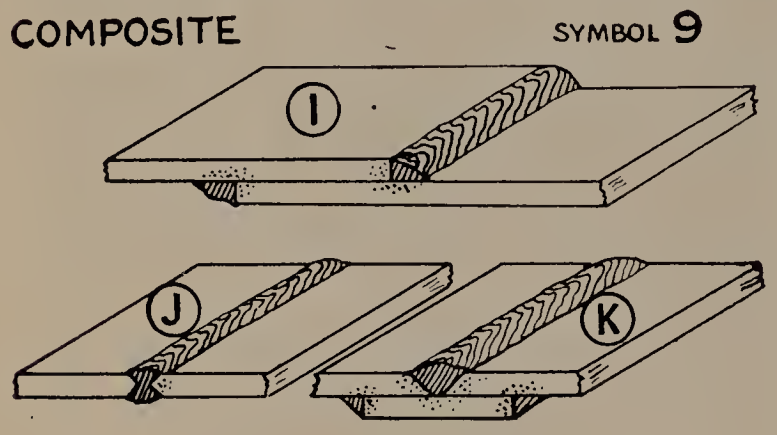
Used for cleaning and de-oxidizing molten aluminum. Made by the Rohde Laboratory, 17 Madison Ave., New York, N. Y.

"Climax"
Trade name for a welding compound for steel. Made by Cortland Welding Compound Co., Cortland, N. Y.

Coefficient
A factor used to determine the expansion of metals by heat. Generally expressed per one degree change of temperature F. The coefficient of expansion of steel is 0.00000636

Cohesion
A condition in a weld which is the result of perfect fusion and penetration, the molecules of parent metal and added material being thoroughly locked or joined. See Adhesion and Fusion.

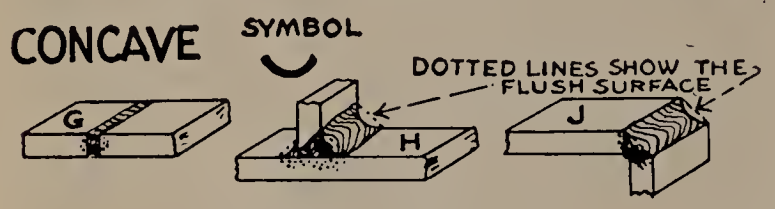
Composite Weld
A composite weld is one in which both the strength and density are of the most vital importance. The strength must be at least as specified for a "strength weld," and the density must meet the requirements of



Composite Weld.

a "Caulking weld" both as above defined. The minimum number of layers of welding material must always be specified by the designer, but the welder must be in a position to know if this number must be increased according to the welder's working conditions.

Concave Weld
Concave is a term applied to a weld when the top layer finishes below the plane of the surrounding material as at "G," or beneath a plane of 45 degrees at an angular connection as at "H" and "J."



Concave Weld.

To be used as a weld of no further importance than filling in a seam or opening, or for strictly caulking purposes, when it is found that a minimum amount of welding material will suffice to sustain a specified pound square inch pressure without leakage. In this "Type of weld" it will not be necessary for the designer ordinarily to specify the number of layers of material owing to the lack of structural importance.

Concrete
Many attempts have been made to "cut" or drill holes in concrete with the oxy-acetylene cutting torch, but no real successful results have been obtained. The torch makes no headway in old concrete which has had a chance to dry out. One operator reports fair success in drilling holes in "green" concrete. Using a large tip with a long tapered carbonizing flame and working from the bottom upwards he averaged one hole in twelve-inch concrete in ten minutes. The holes were about six inches in diameter at the bottom and about one inch in diameter at the top. The process is accompanied by violent explosions of small pebbles, so it is necessary for the operator to provide adequate protection for the face as well as the eyes. This process would not be practicable except in the case of concrete which is quite new or so situated as to retain considerable moisture.

"Conesco"
Trade name for metal electrodes for electric arc welding. Also oxy-acetylene rods and wires. Made by Connecticut Electric Steel Co., Hartford, Conn.

Conical Seat
A joint in the torch head fitting the interchangeable tip.

Constant Current
See chapter on "Electric Arc Welding."

Constant Voltage (Arc Eq'pt)
See chapter on "Electric Arc Welding."

Contact Process
Iron process for producing hydrogen. Incandescent iron decomposes steam which is passed over it. The oxygen of the steam combines with the iron and hydrogen is liberated.

Content
The percentage of any element contained in a metal or other compound, e. g., the carbon content of steel.

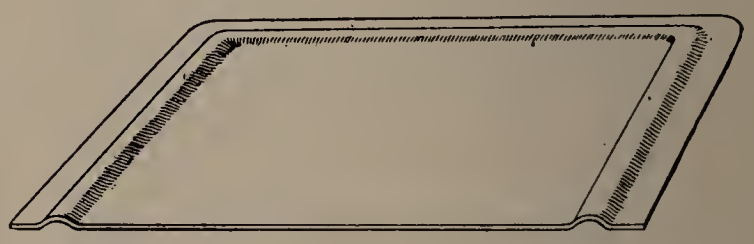
Contraction
The shrinkage of metal while cooling, following a welding operation. See "Expansion."

Copper (Cu)
See chapter on "Oxy-Acetylene Welding."

Copper Acetylide
A substance which forms when acetylene is passed through a copper tube. Very dangerous and liable to explode and cause fire. See "Pipe Lines."

Copper Sulphate ($CuSO_4$)
Bluestone or blue vitrol.

Corrugated Patch
A corrugated patch is a corrugation extending about two inches from the edge, all around three sides of the patch and differs



"Corrugated" Patch

from a "dished" patch insomuch that the latter has only one belly, while the corrugated patch has a continuous run on three sides. See "Boiler Welding" and "Patching Sheets."

Cold Shortness
Result of the presence of oxides in iron. The composition of cold short iron is about as follows: Carbon, trace; Silicon, .203; Phosphorus, .480; Manganese, trace; Sulphur, .030; Iron, 99.287. Cold short iron lacks ductility. In electric arc welding cold shortness is partly prevented by use of the slag-covered electrode. Cold shortness can be improved by annealing. See "Annealing."

"Color-Tipt"
Trade name for welding wire. Made by Wilson Welder and Metals Co., 132 King Street, New York City. See Table of Contents, Catalog Section.

"Columbia"
Trade name for welding carbons, carbon blocks, plates, paste, etc. Made by National Carbon Co., Cleveland, Ohio.

Combustible
Any substance which will unite with oxygen is combustible.

Combustion
The process of oxidization or burning. The term is more customarily given to productions of flame such as we have in the burning of fuel, oil, or gas, but it is conveniently extended to other cases of oxidization such as we encounter when metals are heated a long time in air or oxygen.

"Commercial"

Trade name for dissolved acetylene. Made by Commercial Acetylene Supply Co., New York. See Table of Contents, Catalog Section.

Cost Card

A card used by welders to record the cost of welding operations. Such records must necessarily depend upon local conditions, but a suggested form, which may be altered at will, is illustrated. See "Business Methods."

COST CARD

Date.....

Operator .....

.....

Job .....

Time Required.....

Job No.....	Quantity	Cost
Oxygen	.....	.....
Acetylene	.....	.....
Hydrogen	.....	.....
City Gas	.....	.....
Charcoal (Preheating).....	.....	.....
Kerosene (Preheating	.....	.....
Asbestos	.....	.....
Carbon	.....	.....
Welding Rods	.....	.....
Machining	.....	.....
Assemb'g and Dism't'g....	.....	.....
Cartage	.....	.....
Overhead	.....	.....
Miscellaneous	.....	.....
Total	.....	.....
Plus Profit	.....	.....
Price to Customer....	.....	.....

Countersink

A hole which has been beveled to fit a tapered bolt or rivet head.

Coupling

A threaded sleeve for joining pipes.

"Cox"

Trade name for welding and cutting torches. Made by Cox Brass Mfg. Co., Albany, N. Y.

Covered Electrode Process of Electric Welding

See "Strohmenger-Slaughter Process."

Crater

The bowl of molten metal made fluid by the metal to be welded.

"Cramp"

Trade name for cast iron, copper covered iron, American iron, Vanadium steel, nickel steel, R quality steel or iron and aluminum welding rods, also for aluminum solder and cast iron solder. Made by the Wm. Cramp & Sons Ship & Engine Building Co., Philadelphia, Pa. See Table of Contents, Catalogue Section.

Crank Cases

Oftentimes it is required to weld a large hole in an aluminum crank case, in which case a chill of galvanized iron is provided, backing up the hole and welding against this when filling the hole with aluminum. Galvanized iron is preferable to any other material, such as tin or iron, since it peels away from the aluminum quite readily, and can therefore easily be removed after the weld has been completed. This is undoubtedly due to the zinc content of the galvanizing composition.

The chief value of the use of the chill is that it causes the filler to cool and harden prematurely, thereby preventing it from contracting after the weld is finished. It also prevents the heat of the weld from spreading, which might cause the job to crack back. The chill is fastened in place by a wrought-iron scrap, made in the shape of a boiler crab, which arches the hole. A hole is then drilled through the strap and a similar one through the galvanized-iron plate, the two being fastened together by means of a bolt and nut. In making the weld, the metal is first applied to the inner corners and the space filled up by working toward the center. Just before the center is reached, and when it is impossible to add any more metal without touching the bolt, the strap should be loosened, the bolt removed, and the hold filled with the molten metal. Greater success will obtain if the work is done quickly, handling as large an amount of molten aluminum as possible at a time and covering the entire surface of the galvanized chill in a few minutes. The chill causes the added metal to cool almost as fast as it is connected to the edge of the break. After the weld has been finished and cooled, the chill can be removed by gently prying it away from the weld by means of a cold chisel. The flame of the torch should be kept in motion while performing the work, and should not be pointed toward the weld, but rather across the melting portion; otherwise it is almost certain that the flame will not only injure the metal, but will also burn away the galvanizing if pointed directly toward the weld.

If the arm of a crank case is broken off, there is no necessity for preheating but the job must be set up solidly so that there is no danger of the pieces moving out of alignment during the operation. Proper allowance can be made for the contraction of the welded metal by a slight separation along the break before the welding is started. It is well to warm up the entire area in the vicinity of the break before starting to weld and to weld the metal along the top of the casting first. The caution to take in this repair is to avoid getting too much heat into the casting as this will cause a portion of the metal to collapse. It is common practice to reinforce welds of this nature by building up a generous portion of the adding material. If time does not permit removing the motor from the frame, it will be necessary at least to remove the pan underneath the engine so as to allow the placing of jacks to support the crank case and take the strain off the arms. The broken arm is then unbolted and welded as outlined above. In case the break extends into the body of the crank case, it is necessary to strip the case completely. Make a few tack welds along the break, then preheat all of the portion of the crank case which will be affected by the welding operation. Take particular pains to use a slow preheating fire and to pack the crank case in asbestos or ashes after welding so that it will cool slowly. If the repair is confined to a small lug or boss which has broken off, the effect of expansion can be avoided by placing the crank case in a pan of water so that the portion of the surface on which the lug is to be built up is just a trifle above the surface of the water. A new lug can be built up by adding the welding rod very slowly and making sure that the metal is in fusion at all times. When the bearings are broken out of the crank case, they can be held in place for welding by bolting then to a shaft placed in a normal position, the preheating flame being directed against the outside of the case in the vicinity of the broken bearing which is being welded. If one of the bearings in the case is not broken, the shaft should be separated from it with a very thin shim. This will raise the broken bearings and separate the break slightly. After the weld cools, all the bearings will be in proper alignment. Where the welds are of a very complex nature, the general rule to follow is that the first welding should be done on the inside and all of the work should progress toward the outside of the case.

Crankshafts

Before undertaking to weld a broken crankshaft it is advisable to determine what caused the break. If it was caused by fatigue of the metal there is a good chance of being able to make a satisfactory repair

in a reasonable time, but if it was caused by some external force such as the breaking of a connecting rod or a jam of some kind, the chances are that in addition to being broken the shaft will also be sprung, which often makes the task of reproducing the

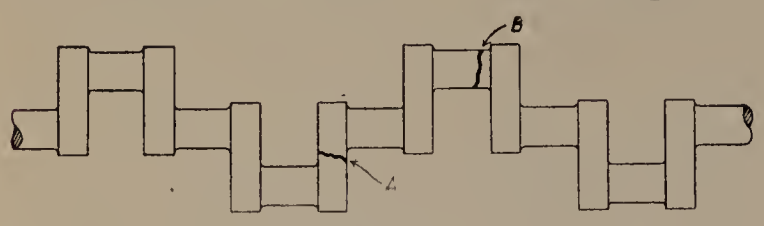


Fig. 1.

original alignment a very difficult one. The next important consideration is the location of the break. If it is in a cheek, as shown at "A" in Figure 1, the original strength can be secured by making a reinforced weld. If the break is on the machined surface, as shown at "B" in Figure 1, there is no chance to reinforce the weld because it cannot be

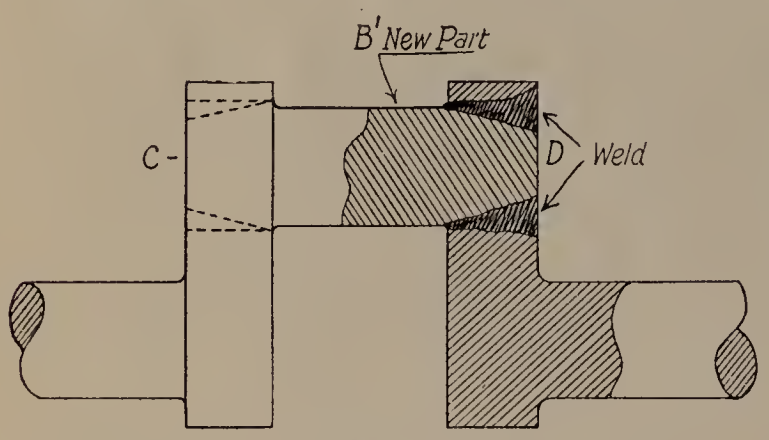


Fig. 2.

built up, and consequently the weld cannot be made as strong as the piece was before breaking. Figure 2 shows how a new part, turned on a lathe to exactly duplicate the broken part, can be inserted by welding to the two cheeks. The new piece should first be tacked in from each end and tried out between centers on a lathe. Faulty alignment can be restored by drawing out the short cheeks under a hammer and closing up the long ones. This is a very important feature of shaft work and requires considerable experience.

Crank Shaft Journals

Worn journals can be built up by the use of a high grade steel filler rod and the tip large enough so that the shaft is kept hot throughout the operation. The metal should be added in beads running lengthwise with the shaft. Best results are secured if the shaft is kept red hot by preheating fire while the metal is being added.

The filler rod should be as small as practicable. Best results on this kind of a job are secured by working slowly.

"Cream City"

Trade name for butt welder, made in both hand-lever operated type and also the hydraulic type. Made by Geuder, Paeschke & Frey Co., Milwaukee, Wis.

Creeping

A regulator "creeps" when the seat does not close against the inlet nozzle, allowing gas to enter the regulator beyond the pressure desired. A creeping regulator is detected by the low pressure gauge. With the valves on the torch closed the hand on the dial does not remain stationary but indicates a higher pressure than it did while operating the torch. A creep of a few pounds is allowable, but when the creep reaches 50 pounds beyond the operating pressure the use of the regulator is dangerous, since the pressure in the body of the regulator may burst the diaphragm on the gauge. See "Use and Misuse of Oxy-Acetylene Equipment," in chapter on "Oxy-Acetylene Welding."

"Crescent"

Trade name for a welding flux or compound. Made by Anti-Borax Compound Co., Fort Wayne, Ind. See Table of Contents, Catalog Section.

"Crescent"

Trade name for welding wire. Made by George C. Moon Co., Garwood, N. J.

Cross Bar

The handle of a regulating screw of a gas pressure reducer or regulator. See Regulator.

Cross Welding

Welding in which the metal is placed in the form of a cross or the letter X. See "Position of Weld."

Current Density

Amperes per square inch of the electrode sectional area.

Cutting

The art of cutting metals with a combination of gases and the torch. The first reference to the art was made in 1888 in a paper read by Thomas Fletcher in England. A German patent was issued to Herman A. E. Menne in 1901 on the use of oxygen for cutting, or as he termed it, "melting."

In September, 1906, a United States patent was issued to Felix Jottrand, a Belgian, on a process to cut plate, pipe and other metal articles with a device using a mixture of oxygen and hydrogen, or other combustible gas, together with a jet of oxygen. It has been claimed that John Harris, of Cleveland, Ohio, cut pieces of steel by this method in 1904.

The only metals that can be cut with good results are iron, mild steel and steels of low carbon content. High carbon steels may be cut with an oxygen jet if properly preheated, depending upon the carbon content. The higher the carbon the greater the degree of preheating. A black heat, for instance, will do for ordinary tool steel, while some of the alloy tool steels would require a low red.

Cast iron cutting is in the experimental stage, but some success has been made in cutting cast iron with the electric arc and gas flames. (See "Cutting Cast Iron").

Brass and bronze plates may be cut by interposing them between steel sheets. For cutting the torch is adjusted to a slightly oxidizing flame. When the flame is applied to the edge of a steel plate the plate quickly rises to a white hot temperature, when the oxygen valve is opened alongside the preheating flame. The white hot metal then takes fire and burns with a shower of sparks. The burning, or oxidizing, metal rolls down the side of the kerf, igniting and burning the metal in its path. The speed of cutting varies with the thickness of metal, size of tip and the skill of the operator.

Unusual applications of the oxy-acetylene welding torch, in various industries, both as a medium for effecting economy or for producing otherwise unattainable results, have become rather common topics in many of the technical publications. On the other hand, very little attempt has been made to indicate what unusual results can be obtained with the cutting torch, either in manufacturing processes, where production is of prime importance, or in such industries as wrecking, scrap cutting, etc., where speed and economy are essentially the controlling factors.

The principle of the cutting torch is in itself very simple, although the actual design of an efficient and durable model brings up manifold difficulties. The process consists in rapidly oxidizing and blowing out the oxide from the material being cut. The metal is first heated locally, and then, a jet of pure oxygen, traveling at a very high velocity is directed in such manner at the preheated metal that the oxidation reaction progresses rapidly through the mass, the oxide freeing itself readily and dropping away. The reaction may be expressed in simple form as iron ÷ oxygen = iron oxide.

The opening produced is known as the kerf. Its width and general characteristics depend upon the design of the torch and method of operation. The number of preheating flames and their intensity, the velocity, thickness, and direction of the cutting jet each produce peculiarities. Oxidized surfaces, rounded upper edges, slaggy lower edges, rough surfaces, etc., may be attributed to one of many causes, provided the material being cut is of average quality, both as to composition and structure.

In order to secure maximum economy in oxy-acetylene cutting, metal cutters should take steps to lower their operating costs by saving gas at every turn. The first suggestion made is the compilation of tables of average results which should be obtained in cutting steel plates with oxygen. Such a table will be useful in checking the work done by capable operators. The workmen should be supplied with these, and also with complete copies of instructions issued by the manufacturers of apparatus. Tubing, valves, regulators, and connections should be constantly subjected to examination for leaks. A careful watch should be kept over the pressure of the gas in cylinders, especially those which are not in use, and those which have been used and set aside for a while. When the pressure in a cylinder becomes too low for cutting the remaining oxygen should be used for welding or preheating, if possible. Before returning cylinders the valve should be momentarily opened, to guard against the possibility of shipping back a full tank. Inexperienced workmen ought not to be allowed to tamper with the nozzle or the interior of the cutting torch, for this often results in enlarging the opening and considerable wastage. Finally, the operators should be required to shut off both the oxygen and acetylene at once when the cutting is completed.

Inclining the Torch When Cutting

According to some authorities straightaway cutting with the hand torch is facilitated by inclining the head of the torch backward after the cut is well started. The degree of inclination will vary somewhat with the thickness of the metal and other conditions. A fairly conservative figure is 65 to 75 degrees angle from the plate behind the torch to the torch head. The effect of inclining the torch is to speed up cutting considerably. The gases directed at an angle preheat the thin edge of undercut metal ahead to the igniting temperature more rapidly than when the tip is held squarely with the plate. The gases and products of combustion turn backward, passing through an arc of say approximately 90 degrees and shooting down and back. Often the drag or lag of the cut will be as much as one-half or even three-quarters inch on half-inch steel. When cutting with the torch inclined it should be uprighted just before finishing the cut in order to sever the metal at the end. Otherwise a wedge of uncut metal will be left due to the oxygen shooting by the corner as the torch reaches the end of the cut. The "drag" part of the cut will be left untouched. Uprighting of the torch cuts this portion off cleanly and lets the piece drop.

Expert hand cutters are able to cut one-half inch steel plate with a very narrow kerf and low oxygen pressure, often working at speeds up to 24 inches per minute and sometimes faster. The experienced cutter learns to follow the cut with great precision, going no faster than permissible but still following the combustion rate so closely that there is little or no loss of cutting efficiency. This is very important. The cutter who tries to work too fast "loses the cut" and makes a mess of things. The cutter who works too slow wastes gas and time, while the one who knows just how fast to cut approximately 100 per cent efficiency in time and gas.

Adjusting the Pressure—It is quite natural that the majority of cutters should increase the oxygen pressure in order to speed up the cutting and blow the slag clear of the metal, but with most cutting torches this procedure has exactly the opposite effect. The oxygen issuing at a high velocity from the tip has a cooling action, and loses much of its oxidizing effect. The result is a poor looking cut, much slag adhering to the under side, and a loss of time and gas. The preheating flame should be kept short unless the work is dirty and rusty, and should be kept as soft as possible. It is not the bright hissing flame, but the hot gentle flame which is so desirable. To regulate the cutting jet, commence with as low a pressure as possible and increase slowly until the pressure is sufficient to penetrate easily the thickness of the metal.

Cutting Holes—To put a hole through a heavy section of steel with a cutting torch, the preheating should be continued until there is a considerable pool of molten metal in evidence. When this step is reached tip the head of the torch to one side a little, then quickly shut off the acetylene and turn on the cutting jet. If the acetylene is not shut off, there will be a flash-back when the molten metal starts to fly.

Cutting Heavy Risers—When cutting heavy risers with the torch, the operator can get a faster start on his cutting by taking a cold chisel and turning up a little curl at the point where it is desired to start the cut.

Cutting Steel Forgings

Special precautions should be observed where forgings are required to withstand severe stresses in service, and where safety of life and property depends upon the quality of the product. For such purposes all such forgings should be normalized after cutting. This means heating to 1,400 or 1,600 degrees F. to produce a refinement of the grain structure. Forgins containing more than 0.45 degrees carbon should be preheated before cutting. Such precautions are not required for low carbon steel, or if they are not severely strained in use but whenever convenient preheating is desirable. Normalizing causes an improvement whether the forging is preheated or not.

Oxygen Consumption

The consumption of oxygen is about the most important factor in cutting, as engineers and plant managers are always on the watch for information that will enable their operators to cut down oxygen consumption without cutting down production. It has been proven time and time again that it can be easily done if the heads of departments would compel their operators to follow the instructions sent out by the manufacturers of equipment with each torch. Each size tip is so drilled that it operates at its highest heat efficiency if the pressures are used as prescribed. For each thickness of metal to be cut the instructions tell what size tip and pressure to use and at what speed the torch should travel. This isn't guess work, but the result of thousands of experiments.

It does not take long for a hand cutting operator to get in a rut. Instead of trying to do his cutting with the least amount of oxygen, he will put into his torch a tip three or four sizes too large for the thickness to be cut, and use an oxygen pressure absolutely out of proportion to what he should use, just because it was easier. This is the chief cause of oxygen waste.

It requires a given amount of oxygen to consume or oxidize a given amount or weight of steel, and if a greater amount of oxygen is used without adding additional weight to the steel, a waste of oxygen is the result. A laboratory report from a well-known metallurgist states that the most economical proportions are one cubic foot of oxygen to twenty-two hundredths pounds (.221 lbs.) of steel.

The report mentioned arrives at these figures substantially as follows:

Oxidation of Iron

Black iron oxide has the chemical formula Fe_3O_4. That is, three parts of iron by weight combine with four parts of oxygen by weight.

The atomic weight of iron=56.

The atomic weight of oxygen=16.

Or, the molecular weight of black iron oxide (Fe_3O_4) is, (56x3)+(16x4) or 168+64=232.

That is, say we have 232 lbs. of black iron oxide. Of this amount, 64 lbs. would be oxygen and 168 lbs. would be iron. Or to find out how much iron one pound of oxygen would oxidize, we would have the equation.

64 : 1=168 : X or X=2.62 lbs.

Therefore, one pound of oxygen will oxidize 2.62 lbs. of iron.

And since one pound of oxygen=11.94 cu. ft. or 12 cu. ft. in round numbers, it follows that one cubic foot of oxygen will oxidize only one-twelfth of this, or

$$\frac{2.62}{12} = .22 \text{ lb.}$$

In trying to check this up, one concern made some very interesting tests, covering quite a period of time with both hand cutting and machine cutting, selecting half inch steel plate to experiment on, using various size tips and pressures, and also various speeds.

One hand cutting test was cutting over 5,000 linear feet of ½ inch plate, covering 17 days cutting at 8 hours per day, or 136 hours. This time covers moving from one side to the other, but does not include changing of cylinders, as a 10 cylinder manifold was used, cylinders being changed before starting in the mornings. Three different size tips were used at varying pressures, but the best results were obtained with the smaller tip. The best day's cutting was used, which was 393 linear feet cut, 565 cubic feet of oxygen consumed. This means his best average linear feet cut per hour was 49 feet. The speed of cutting averaged 8.16 inches per minute, and oxygen consumption 1.43 cubic feet per linear foot.

To give an idea as to what the human element actually means in hand operation, on one of the seventeen days having the same identical working conditions and the same thickness of plate to be cut, weather conditions also good, the operator cut as low as 258 linear feet, another day 298, another day 347, and another 360. This proves that a hand operator cannot keep up a constant speed several days at a time.

In machine cutting tests, the same size tip and lower oxygen pressures were used, using half inch plate, each plate 12 feet long, and obtaining a speed of 18 inches per minute and oxygen consumption 1½ cubic feet to each 18 inch of cutting. The width of cut was ⅛ inch, and as one square foot of ½ inch plate weighs 20 pounds and dividing this into ⅛ strips we find we have 96 strips, dividing this into 20 pounds we find that we have oxidized .21 pounds of steel with each cubic foot of oxygen consumed, which is close to the figures given in the report. All of the machine cuts were smooth and straight. 2,500 linear feet were by machine.

Cutting Tanks and Cylinders

The scrap dealer who purchases old metal tanks, barrels or cylinders should not fail to ascertain definitely the uses to which such containers have been put. If they have held combustible gases or liquids, or even certain dry chemicals they are a serious source of danger.

In many cases the former use of the container may not be suspected, but there are other instances where it should be obvious to a dealer in scrap. For example, everyone engaged in the production of scrap should recognize instantly cylinders used for the storage and transportation of compressed gases. Such cylinders are usually the property of the companies that produce the gases so stored and transported, and their names are generally conspicuously marked on the container in a manner difficult to efface—commonly, by stamping the metal with a die.

Whenever tanks that have been used for explosive gases, liquids or substances are offered for sale as junk, the person offering them should be advised as to their character and warned not to dispose of them for reduction; and the nearest office of the manufacturer, whenever the name is obtainable, should be notified without delay.

There is only one perfectly safe and satisfactory way of cleaning gasoline storage barrels and tanks; that is, by flushing out with live steam for about fifteen or twenty minutes.

Cutting, Cast Iron

In practice, cast iron cutting differs from steel cutting in that:

(a) It is necessary to use heating flames having an excess of acetylene.

(b) It is necessary to hold the torch nozzle farther away from the metal.

(c) It is necessary to preheat for a longer period for cast iron than for steel, since the cast iron must be almost molten before the cutting reaction will start. Steel ignites at a temperature well below its melting point.

(d) It is necessary to continually oscillate the nozzle to maintain the cut.

A cast iron cut, if properly handled, and if the material is of good quality, will have an appearance about equal to that of a fair cut in steel.

The time required for cutting a given section of cast iron is about twice that required for cutting a similar section of steel. This makes the cost considerably higher in the instance of cast iron and tends to restrict its applications in many places where one might suppose it would be generally useful. For example, the inexpensive methods employed for removing risers from castings in iron foundries preclude the use of oxy-acetylene as an economical means of performing this class of work. Further, the cutting off of risers from chilled iron castings is usually not practical because the surfaces cut are likely to crack or check, due to local heating.

Cast iron cutting is already being appreciated in the steel mills. In those plants cast iron cutting is used daily in that and other industries for removing broken machinery parts such as pinions, gears, flywheels, housings, etc. The removal of such parts by old methods usually required several days because of frozen shafts, bolts and the like. With the cutting torch the broken part, and sometimes parts adjacent to it, are cut quickly, the parts removed, repaired, or new parts installed all within a few hours.

Instructions for Cutting Cast Iron

The torch manipulations for cutting good grades of cast iron and for cutting poor grades of cast iron are quite different and are both described below. Although there is a difference in the manipulation of the torch, the oxygen pressures used and the adjustment of the flame are the same for both grades of metal.

Method for cutting good grades of Cast Iron:

(1) Adjust oxygen cutting regulator to give the correct pressure for the work to be done, having the cutting valve open. Then close cutting valve.

(2) Open oxygen valve one-half turn and acetylene valve fully and light torch. Open cutting valve and adjust acetylene valve to give flames having an excess of acetylene, the length shown in the cutting chart. Then close cutting valve.

(3) Hold torch so that the nozzle points backward at an angle of 45 deg., with the inner cones (not the excess cones) ⅛" to ¼" above the surface. give the nozzle a swinging motion describing semi-circles over the end of the line of cutting and heat a semi-

circular area about ½" to ¾" diameter to a bright cherry.

(4) Move nozzle just off the heated edge, open cutting valve quickly and move nozzle (at 45 deg.) forward along the line of the cut with the same swinging motion.

(5) While advancing the nozzle gradually straighten it up so that it is about 75 deg. pointing backward when at the inner edge of the previously heated semi-circular area.

(6) Advance nozzle about ¼" to burn off the molten surface, then quickly move it backward to burn through the comparatively dark layer and lower section, then hold it steady for a moment to heat the upper surface.

This movement can be best practiced by counting as follows: 1 forward, 2 back, 3 hold; 1 forward, 2 back, 3 hold, etc., etc.

(7) Continue moving nozzle in this manner at the rate of about one complete cycle per second.

(8) When the far edge is reached, carry nozzle over the edge and across the other surface, holding it at about the angle of the lag, and cut through the lag section.

Method for Cutting Poor Grades of Cast Iron

Follow the directions given for cutting good grade grey iron, except that instead of using the peculiar motion explained, advance the nozzle slowly, describing semi-circles from about ¼" to ½" wide across the line of the cut, holding the torch at about 75 deg. pointing backward.

Notes on Cast Iron Cutting

In cutting cast iron a dark layer will be found extending down from the top surface about 1" to 1½". Below that layer the material will be bright, having an appearance about the same as steel.

Be sure that the forward and backward, or the semi-circular movement of the nozzle allows the torch to cut almost perpendicularly through the dark layer. The lag must not start until below that section. Particular attention must be paid to this condition.

If cut is lost, move nozzle back along one edge of the kerf about ½" and describe semi-circles lapping that edge and that point where the cut stopped. If the cut is not readily resumed, carry the semi-circles over to include both edges of the cut and the point where the cut stopped.

Always wear heavy asbestos gloves and suitable clothing to protect the body, face and head, because cast iron cutting is a very must hotter operation than steel cutting.

Always make sure of ample protection from the heat before starting so that it will not be necessary to stop the cutting operation to take shelter or provide further protection.

Cast Iron Cutting Chart

Thickness of metal, in	Length of Excess acetylene, in.
½ to 2	1 to 1½
3 to 12	1½ to 2

Steel-Cutting

The question is often asked, "What does it cost to cut steel?" The answer is dependent upon so many factors entering into the question that hard and fast figures governing it are impossible to arrive at. The human element is subject to the greatest fluctuation. The skill of the various operators may vary results 100 per cent. Then too, a thin scale of rust or boiler scale (in scrap cutting) may be the cause of 50 per cent increased consumption of gases and time. Using too large a tip, too high pressure, or too small a tip or too low pressure, will increase the cost. Under different conditions, different combustible gases may be used to advantage, such as hydrogen, coal gas, natural gas vapors, or blau gas. In cutting, where frequent stops are made requiring quick starts, the hotter flames, as oxy-acetylene or oxy-hydrogen should be used, but in making long cuts, a gas producing a lower temperature may be used with good efficiency. Even when a machine operated torch is used, the same efficiency will not be maintained with the same combination of gases for different thicknesses of steel. Cutting with oxy-acetylene predominates in a great many plants, due to the fact that an operator may instantly change torches and use the same gases for welding which is impossible with the other gases.

A safe rule to follow is to obtain the purest gases possible, use oxygen pressure only sufficient to clean the kerf neatly, and choose a size tip that may be regulated to heat the steel just enough to allow the cut to proceed rapidly without interruption and one in which the oxygen jet is as small in diameter as is consistent with the work in hand. To get consumption of oxygen, divide the number of pounds used by 9 (in a 200 cu. ft. drum and by 18 in a 100 cu. ft. drum) to get the cubic feet. To get the number of cubic feet of acetylene used, weigh the cylinder before and after the operation and multiply the decrease in pounds by (no. of cu. ft. per lb.—13). Make these figures carefully and after getting the cost in dollars, divide by the feet of cut and the result will be the gas cost for lineal feet. Cutting with oxygen is a chemical reaction between iron and oxygen and as in all reactions, the more pure the elements are, the greater will be the rapidity of the chemical action. This is so characteristic of cutting that with oxygen with impurities of more than 15% it is impossible to get any satisfactory results and with even several per cent impurities, marked difference is noted.

Cutting Torch

A torch or blow-pipe with one or more heating jets and an oxygen jet, used for cutting metals. See "Cutting."

Cutting (Under Water*)

The process of under-water cutting was already known before the war and very interesting results had been obtained in France and Germany. In the port of Hamburg, particularly, the experiments and results obtained were surrounded with mystery.

In France, this problem may be considered as solved, for the last few years, and the practical realization of this process has been undertaken by the "Soudure Autogène Francaise" (French Welding Society) which has perfected an oxy-acetylene blow-pipe entirely special, called under-water cutting blow-pipe. Trials of this blow-pipe, started before the war, have given very encouraging results, but were abandoned during the hostilities.

Two years later the question was taken up again but under a different order of ideas: by using the electric arc.

It is a known fact that it is impossible to prime an electric arc under water and during the trials insulated metallic electrodes were used, then those made of carbon and finally, without success, however, hollow electrodes allowing insufflation of an oxygen jet.

For several reasons, the experiments relative to cutting by means of an electric arc were interrupted and the Society "La Soudure Autogène Francaise" resumed the perfecting of the oxy-acetylenic blow-pipe, which after having gone through several transformations and modifications of details, was presented to the National Navy in 1917.

The principle of its operation is based on the possibilities of an oxy-acetylene flame to be insulated from the bulk of the water in which it happens to be, if it burns in a space fed by the air driving back the water. This result is obtained by covering the nozzle of the cutting blow-pipe with a bell of proper shape and size which receives compressed air through a canalization.

**Marcel Piette in Revue De La Soudure Autogéne, with additions by the Editors.*

The shape of the blow-pipe is that of a "Oxy-Secator" comprising the bell to which is connected a tube with fittings carrying the air which is distributed to the bell through two separated connections. This air is regularly distributed through specially studied channels which come out into the bell through an annular aperture surrounding the heating nozzle. The air bell is provided with three round shaped guides keeping it away from the matter to be cut; these guides also maintain the flame to an invariable distance from the said matter.

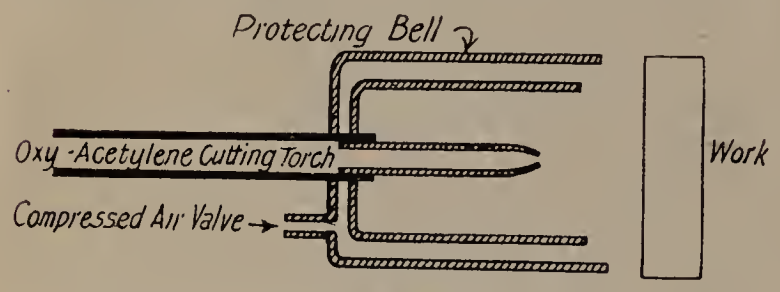
The starting, regulating and operation of this blow-pipe are the same as any cutting blow-pipe; besides the necessary gas, a supply of compressed air regulated to a proportionate pressure to that of the liquid center in which it is operated, must be kept, that is to say, varying with the depth in which the work is done. The oxygen and acetylene pressures, this last gas being always used under dissolved acetylene form, perform themselves the function of water pressure to the depth under consideration.

Before going under water, the diver who is to perform the cutting operation lights and regulates his blow-pipe outside, then he orders the compressed air to be turned on, regulated beforehand to the necessary pressure, and may then dive with the apparatus all lit up.

The green lights of the oxy-acetylenic flames visible among the tumultuous boiling of the water, when the blow-pipe is not deeply submerged, allow one to follow the operation.

The work of the operators is very difficult on account of the strength required to apply the blow-pipe against the part to be cut, of the visual attention necessary for the execution of the cutting, of the difficulty of striking at the same spot when needed and especially of the deafening noise caused by the pressure of the escaping gas amplified by the resonance of the metallic helmet.

What is more, the diver's movements are often hindered by the current and he must be perfectly familiar with his diving apparatus so that he may have a great part of his attention for the operating of his apparatus.



French Type Under-Water Cutting Torch.

Except for these difficulties, cutting under water is done as in the regular manner, that is to say, by previously bringing to red heat, by means of the heating flame of the blow-pipe, a part of the metal sheet or of the piece to be cut, by throwing on the oxygen jet and then by bringing the blow-pipe gradually closer.

The results obtained during the trials were most encouraging. Thus, at a depth of 5m 20 iron sheets of a thickness of from 8 to 22 mm were cut. A cut of 400 mm long was made in six minutes in a metal sheet of 20 mm.

Since then, a certain amount of posts have been established in the French, English and American Navies, which have created a special personnel for this new application of the cutting-blow-pipe to the works of demolishing under water, the sea or a river.

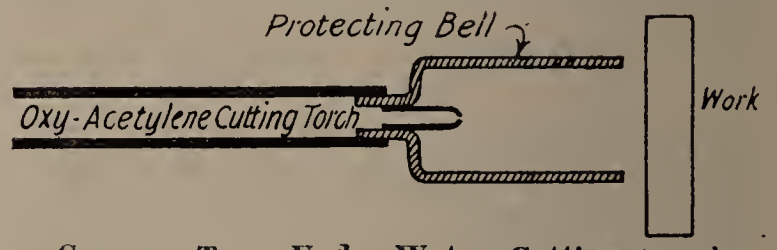
Before ending, we wish to mention a very interesting accessory for the cutting blow-pipe which permits its lighting it while submerged. This apparatus is due to an ingenious inventor, Mr. Corne, and is composed of a movable fitting equipped with springs, attached to the bell and which is connected to a brass tube containing a powder which is inflammable by contact with water. The tube is closed by a rubber stopper equipped with a ring so that it may be taken off at the desired time. The fitting equipped with springs allows the lighting tube to present its aperture facing the nozzle of the blow-pipe at the time of the lighting and is pushed back after so as not to prevent the cutting operation.

Thus the loss of time resulting from the diver being obliged to come back to the open air with the blow-pipe to light it, is prevented by the use of this ingenious system. The operator equips himself with these "matches" at the time of the diving and can thus start his blow-pipe should any accidental cause provoke its extinction.

The technical part of the process which is here described is evidently only in the experimental stage and will undergo as well as the apparatus, some improvements and transformation. Even though it has a limited field of applications, the cutting blow-pipe for under water purposes has already shown its usefulness and will render better services in the future for salvage work, clearing away, etc.

German Type Sub-aquaeous Torch

The type of under-water cutting torch developed by the Germans was somewhat less elaborate. A cup-shaped nozzle was provided to fit over and protect the tip of the cutting torch, and the pressure of the gases in this nozzle was relied upon to keep the

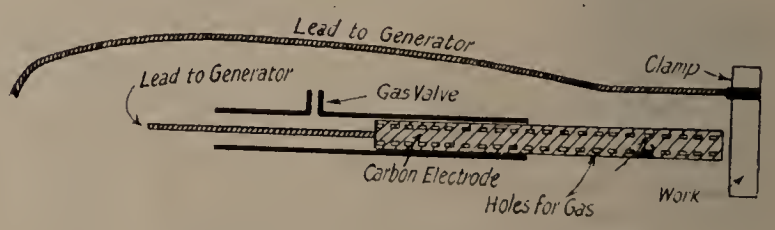


German Type Under-Water Cutting Torch.

water away from the cutting jet, as well as to scatter the slag while it was still in a liquid state. With this type of construction it is impossible to light the torch under water, and the cutting must all be in a horizontal direction, or nearly enough so that the water cannot enter the protecting nozzle. It can be operated at shallow depths only, because the pressure of the gases in the nozzle must necessarily be much greater than the water pressure at the depth of the metal to be cut.

Gas-Electric Submarine Torch

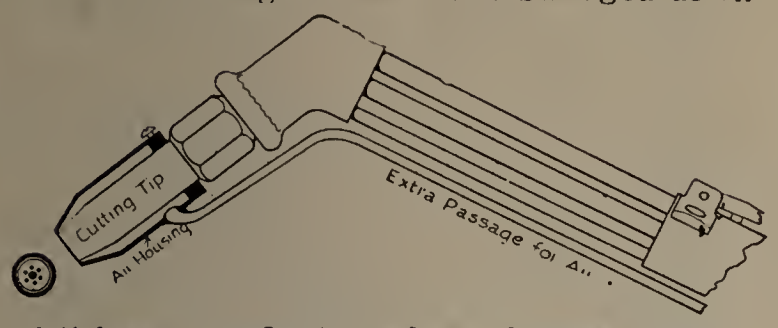
The most recent development in under-water cutting is an adaptation of the carbon electrode electric arc cutting process, in which the carbon electrode is pierced by two small brass tubes, through which a special cutting gas is supplied from the surface. The gas oxidizes and blows away the metal melted by the arc, and also converts the surrounding water into steam, thus making a gaseous envelope for the arc. The combined action serves to greatly speed up the operation of the cutting electrode, as the metal is blown aside before it has a chance



Gas Electric Submarine Torch.

to solidify. This device has been used successfully for cutting metal between three and four inches thick at a depth of about fifty feet, and on heavy plate at a depth of seventy feet. Its limitations are less serious than in the case of the gas cutting torches because the operation of the cutting arc is not hindered by water pressure so long as the cutting gas can supply enough heat to vaporize the surrounding water and enough force to scatter the molten metal. (See "Electric Arc Cutting" in chapter on "Electric Arc Welding.")

Any standard cutting torch can be converted into an under-water cutter by providing an extra air supply as shown in the sketch below. The housing consists of a piece of thin brass tubing a little larger than the cutting tip, with one swedged down



Fitting a Standard Torch for Cutting Under Water.

to leave only a small space between it and the tip, and at the other end a collar to make a snug fit over the upper end of the tip. A hole is punched in the side of the tube and a piece of copper tubing fitted in it. This piece of copper tubing is made to conform to the under side of the torch and laid right up against it the entire length. Near the adjusting valve of the torch an extra valve is brazed on and to this valve a compressed air hose is connected. The air pressure necessary for cutting is easily estimated by figuring the water pressure at one pound for every two feet of depth and adding fifteen to twenty-five pounds. This will usually be enough to keep the water away from the work and allow the operator to work rapidly.

MECHANICALLY OPERATED CUTTING TORCHES.

"The Radiagraph"

The Radiagraph is a portable machine cutting torch weighing about 50 pounds which may be used for cutting to straight or curved lines. The machine carries the cutting torch on a horizontal arm adjustable vertically and laterally, and provided with two swivels which permit it to be set at any angle, sideways for beveling or in the plane of the cut when cutting off risers, etc. The motor is connected to the tractor wheels through a gear box which provides for a wide range of feed speeds and for feeds in either direction.

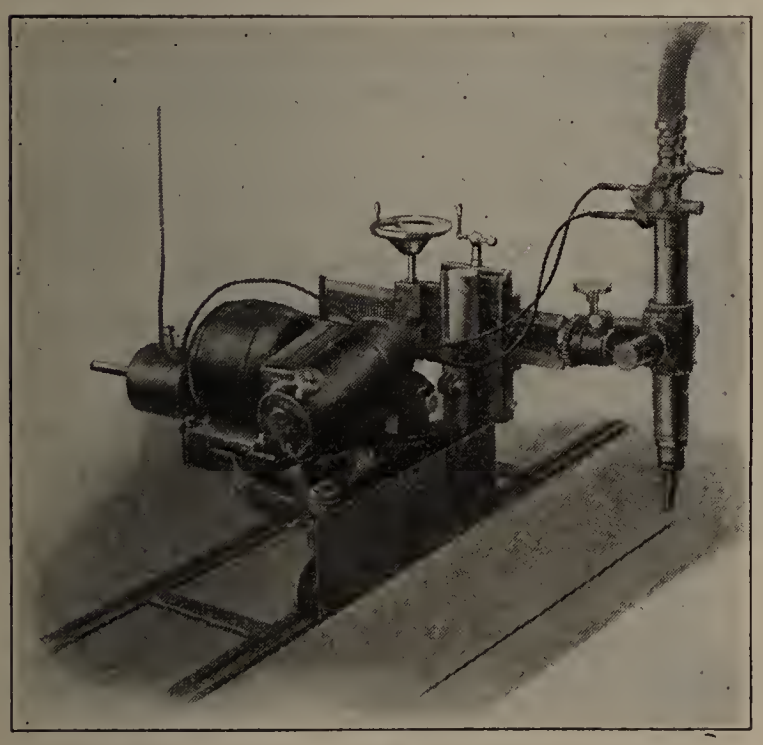


Fig. 1. Radiagraph for Line Cutting.

When cutting to straight lines the Radiagraph runs in a grooved steel track which is furnished in sections about five feet long. These sections may be joined to make any length required. When cutting to arcs and circles the machine swings on a radius bar around a screw point resting in a punch mark made in the plate being cut. The Radiagraph is used in boiler shops and shipyards for straight line and circle cutting, beveling to caulking angle, etc.

When cutting circles with the Radiagraph the inside tractor wheel is removed and a screw pivot is set on the radius rod, the point of the pivot resting in a center punch mark. If a larger circle is to be cut the small radius rod can be removed and a larger

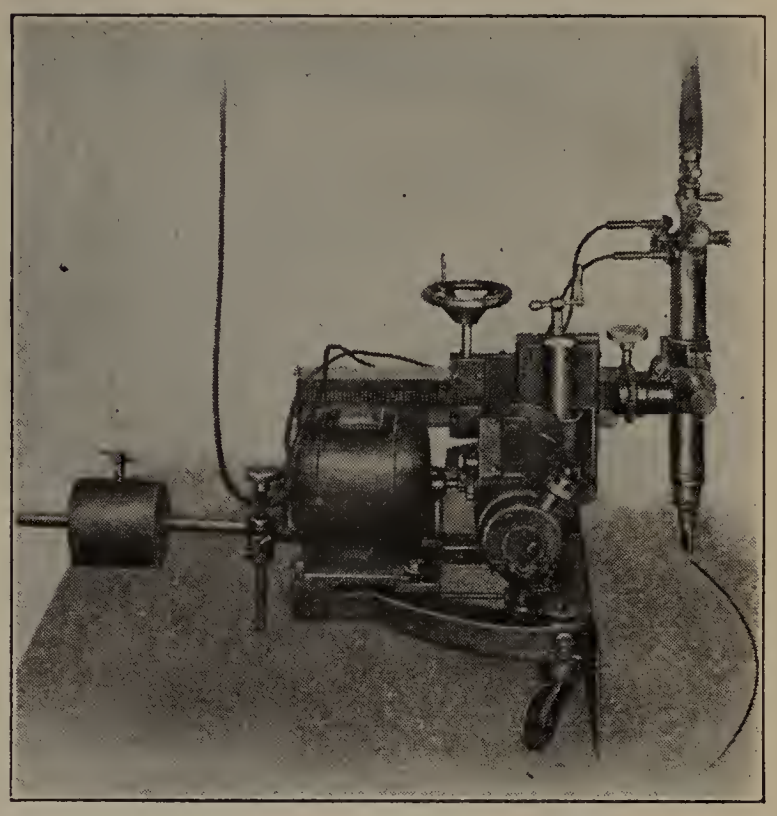


Fig. 2. Radiagraph for Circle Cutting.

one set in. Circles of any diameter can then be cut. Note that the trailer wheel is set to the radius of the circle.

Fig. 3. Slabs Prepared for Mechanical Cutting.

It was built for the cutting of straight lines and circles, but with a little ingenuity it can be used for cutting of squares, ovals, and long irregular cuts. Figure 3 shows steel slabs being laid out prior to cutting with the Radiagraph. These plates were 9 inches thick and the rounds to be cut were 31 inches in diameter. The machine can be seen actually cutting one of these rounds. There were eight linear feet of cutting to each circle. Cuts were made at a speed of 4 inches per minute or 24 minutes of actual cutting time per circle. Figure 4 shows a "close-up" of the finished cuts, also the machine. Note the smoothness and accuracy of these cutting surfaces. These slabs were cut into round pieces for forging purposes.

Figure 5 shows the Radiagraph set on 1½ inch plate for cutting bevels. "A" is the cutting oxygen valve, and "B" shows the electrical switch for stopping and starting

the machine. When the cutting oxygen valve is turned straight up and down, it releases the oxygen cutting pressure and at the same time forms a contact with electrical switch,

Fig. 4. Finished Cuts.

"B," and both motor and cutting are started. At the finish of the cut, oxygen cutting pressure is shut off, and motor stops.

In one of the largest mills in the Central

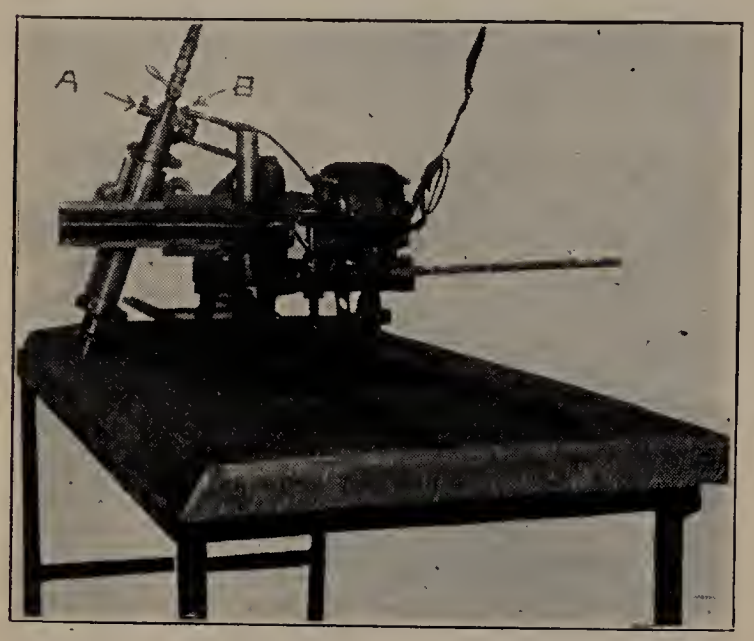


Fig. 5. Machine Set for Cutting Bevels.

West, engineers were confronted with a proposition that called for a cut to be made on ½ inch steel plates. These plates were approximately 8 ft. wide by 30 ft. long, as per Figure 6. The cut was 12 ft. in length and of sixteen different radii. After cut-

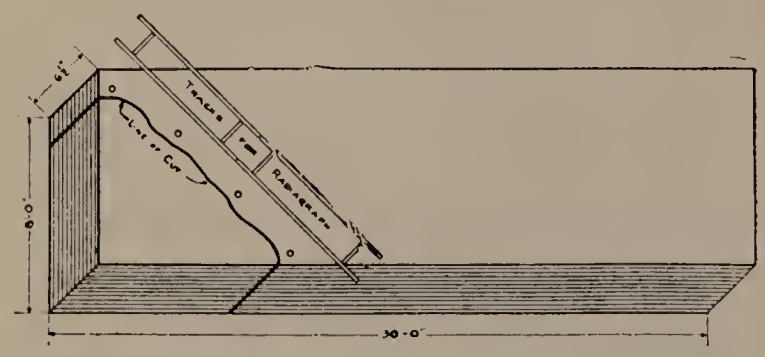


Fig. 6. Twelve Plates Assembled for Cutting.

ting they had to fit accurately other pieces for forms. Hand cutting was figured on, and it was found that too much chipping and grinding was necessary in addition; also to continue hand cutting involved the purchase of at least ten new hand cutting equipments. The engineers then turned their attention to machine cutting. A template was made exactly like the cut, with the various radii, out of ⅛ inch black iron, 15 inches wide. A special torch was built, which swung freely on the post of the machine, and a spring attached to the post and torch to keep the torch against the template, so that while the Radiagraph would run on a straight track the spring would hold the torch to the template, making this cut exactly as laid out on blue prints.

In cutting one plate at a time, the set speed was 22 inches per minute and it was found that this was too slow, as these plates were to be delivered at a certain time that was fast drawing near. Four plates were then stacked up and cut one at a time. Eight plates were next stacked up, one on top of another, and cut at one time. These two cuts were so successfully made that it was decided to cut twelve plates simultaneously. After these plates were set up a bolt was set every three feet to hold plates as close together as possible. The speed of the Radiagraph was set at 12 inches per minute. Thus the cutting speed on the single ½ inch plate was 144 inches per minute or 720 feet per hour. The cut was so successfully made as to speed, smoothness, straight vertically, and so clean and to the line, that they were ready to be installed without any further labor. The balance of the plates were cut as described.

"The Pyrograph"

The Pyrograph is a boiler shop cutting tool built on the lines of a radial drilling machine, and is designed to cut the flange of boiler heads, combustion chamber heads and other flanged members to height and calking angles in one operation. A carriage mounted on ball bearings and traversing on the radial arm supports the torch. The carriage follows any shape of flange automatically with no other guide than the flange itself, feed and friction rolls engaging the opposite sides of the flange which thus acts as the track. Cutting of the common thicknesses of boiler plate is done at the rate of about one foot per minute. One man with the Pyrograph can cut the flange of a 15-foot Scotch boiler head to height and calking angle in one hour; this would ordinarily require an expert using a pneumatic chipping hammer from thirty to forty hours to accomplish.

"The Oxygraph"

A pantograph is employed in the Oxygraph to support and guide a cutting torch while reproducing diagrams drawn on paper or built into metal templets. The No. 1-A Oxygraph consists of a bed supported on pedestals, carrying a horizontal pantograph frame on which is vertically mounted a machine

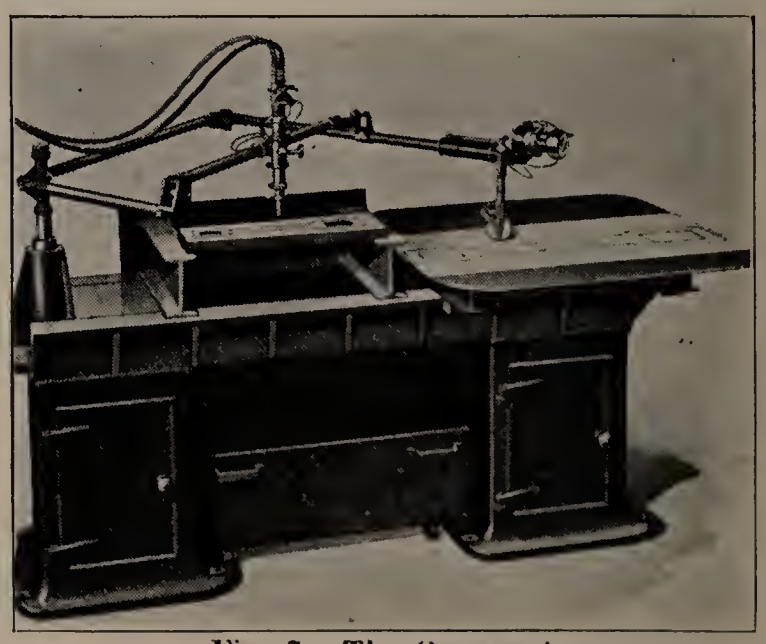


Fig. 7. The Oxygraph.

torch. A table conveniently located supports the drawing or templet which is to be reproduced by a cutting in steel. The machine reproduces drawings in half scale, the torch movement being reduced one-half by the pantograph action. A tractor wheel mounted in a swivel standard and driven by

a small electric motor through a train of gears rolls over the drawing or follows the templet shape, guided by the operator. Pointers on each side of the wheel are provided, either of which may be used to follow the line when working on a drawing, depending on whether the machine is cutting to an exterior or interior design. The speed of the motor and the resultant feed motion are regulated by an electrical governor through a knurled button on the end of the motor.

The No. 2 Oxygraph embodies the same general principles but has two pantographs mounted side by side and connected to a horizontal bar mounting one or two machine torches and the tracing wheel and motor. It has capacity adequate for heavy forgings and large plates. A supplementary lateral bar is furnished with this machine to carry the torch and tracing wheel when cutting openings in plates of large areas such as the stiffening members in torpedo boats, etc.

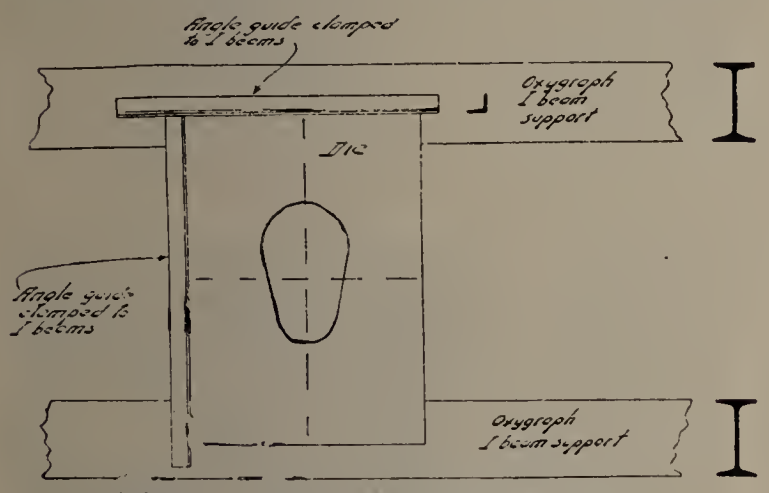


Fig. 8. Set-up for Cutting Dies.

Punches, dies, stripper plates and bolsters are cut in tool shops with the Oxygraph with resultant large savings of time and cost. The usual practice in making a cutting or trimming a die is to plane the block on the top and bottom, bevel the sides, lay out and drill holes to the line, cut out the walls between the drilled holes with a broach or drift, and finish with hammer, chisel and file, or by backing out with a shaper or slotter. Almost invariably a die made in this manner warps and twists in the process which requires either replaning on the bottom or shimming up in the bolster. The removal of the mass of steel in the center of the die relieves internal stress and lets the block warp out of shape. When the rough die block is cut out on the Oxygraph, all troubles of this sort are eliminated and the danger of cracking in hardening is reduced to a minimum. The rough die block is preheated and cut before planing, using a paper drawing to guide the tracer wheel.

Fig. 9. Machine Cutting Twelve Plates at Once.

When the opening has been cut, the die (still hot) is placed in an annealing box, covered and left to cool. When cold it is planed and finished in the usual manner with the assurance that internal stresses have been relieved.. Finishing the die to precise dimensions and backing out for clearance is done in the usual manner. Not only is the Oxygraph useful for blocking out dies but it may be used also to cut the stripper plates and bolsters.

In the cutting of die steel with a carbon

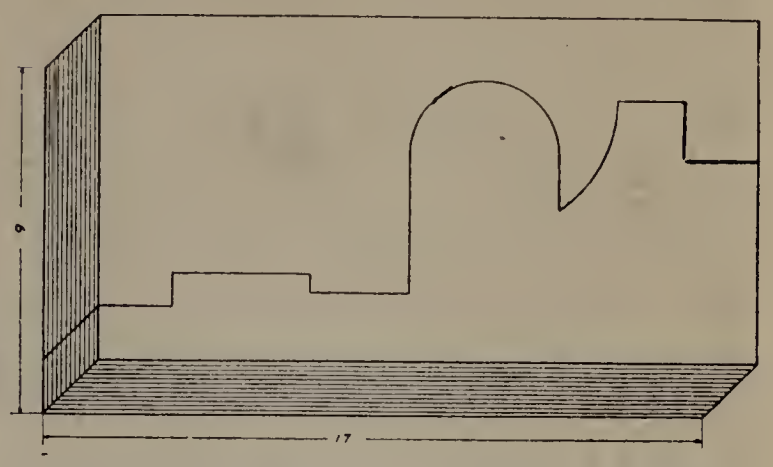


Fig. 10. Irregular Cut Made by Oxygraph.

content above .75 preheating before cutting is absolutely necessary to insure a smooth accurate cut. All die steels below this carbon content can be cut without preheating.

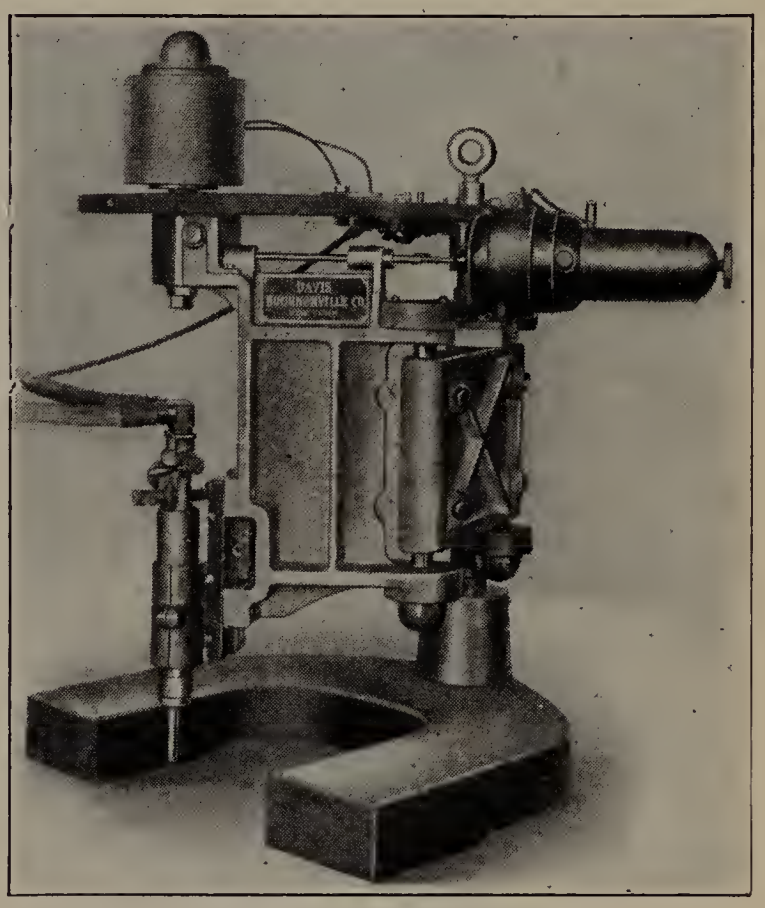


Fig. 11. Camograph.

This necessitates the taking of the die away from the jig after it is lined up, preheated to about 750 degrees F. or over and then it is put back in jig and cut. In **Figure 8 note** that two 6 inch "I" beams are set on the frame of the machine, to support the die. Two 1½ inch angles are then clamped to the I-beams to hold die in place. The shape to be cut is scribed on die and a little off the line of cut a $\frac{1}{8}$ inch hole is drilled for starting. Two straight lines are also scribed, both ways, through the middle of die which enables the operator to set his drawing in the correct position. As this die is set up in jig when cold, then taken off and heated and placed back on jig ready to be cut, it is necessary to make provisions for the difference in size of die due to expansion caused by preheating. To overcome this a few strips of newspapers are placed between the angle irons and die when it is first set up, and the die is cold. When the piece to be cut is taken off the machine to be heated,

the pieces of paper are removed from jig and hot die put back again to be cut. Experience quickly teaches how much allowance it is necessary to make for various sizes and thicknesses of dies.

Figure 9 shows the cutting of twelve pieces of ¼ inch steel plates, one piece being laid upon the other, at the same time, on the Oxygraph. The drawing is laid out on the tracing table and is twice the size of the

Fig. 12. Ellipsograph Cuts.

pieces to be cut. Figure 7 shows a line drawing of this cut and will give a much better idea of the irregular forms that can be cut on this type of machine.

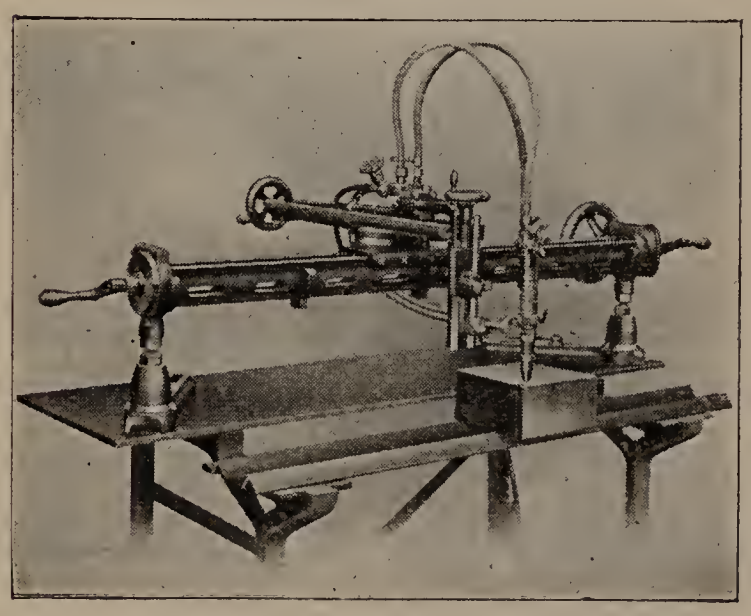


Fig. 13. Gewe Universal Cutting Machine.

"The Camograph"

A special machine for cutting hand holes and other shape openings in boiler plates, and headers is provided in the Camograph. The machine may be used also for cutting gear and rack teeth in steel plates and castings and for repetition cutting of dies and other small work. The torch is mounted on a double-jointed arm, and is guided by an internal cam which causes the tip to follow in a prescribed path. A special cam is required for each shape to be produced. The cam roller is held to the cam surface by magnetic attraction

Holograph

This is a specially designed machine for cutting round holes from ½ inch to 2 inches in diameter, using the oxy-acetylene torch. Adapted to cutting holes in steel structures, rails and plates.

Ellipsograph

This machine is a hand operated device for controlling the motion of the oxy-acetylene cutting torch, and is designed to make possible the rapid cutting of circles, ellipses, ovals, and a great variety of odd shapes, from sheet metal or plate, in boiler works and similar shops. The illustration shows some of the figures that can be cut with it. No patterns are used. Its capacity for elliptical forms is 20 inches by 32 inches; for circles, 20 inches; and for straight lines, 20 inches.

"Gewe" Universal Cutting Machine

This machine is intended for heavy work, such as cutting squares and other shapes out of billets to prepare them for crank-shafts. It has three movements: longitudinal, transversal and vertical. The first two movements if worked singly or together can follow any straight or curved line in a plane, and the third movement allows it to overcome the surface irregularities of the rough billet. It is mounted on bottom plates so that it can be set directly on the work piece and moved from one point to be cut to another.

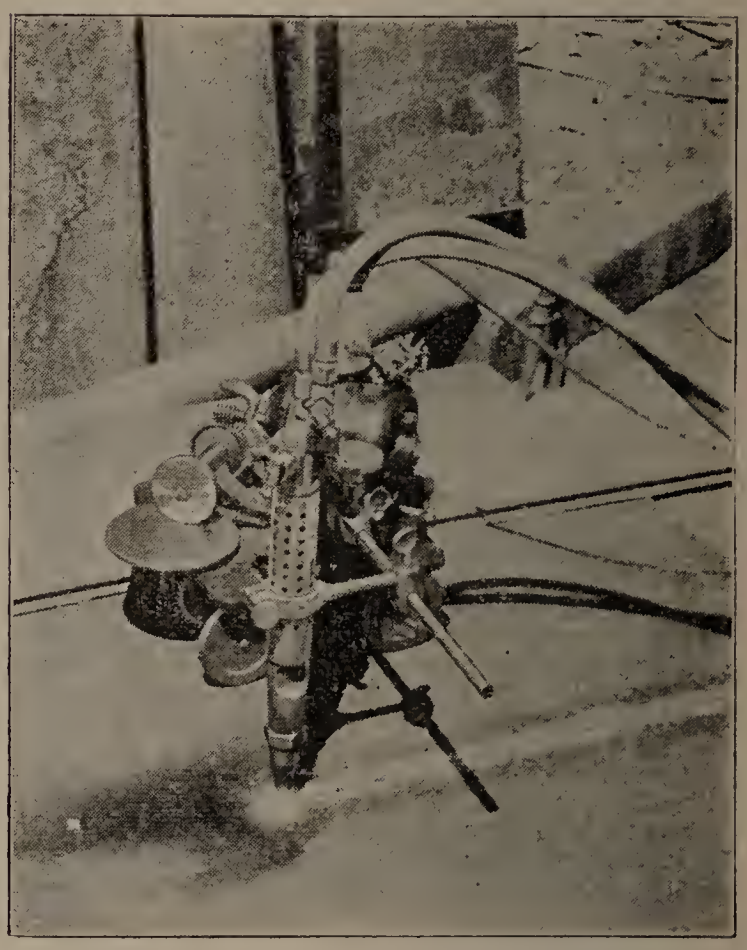


Fig. 14. Gewe Automatic Plate Cutting Machine.

"Gewe" Automatic Plate Cutting Machine

This machine is a motor driven cutting torch for plates, girders and other steel shapes. It can run either on tracks or directly on the plate to be cut. When making long cuts it will keep its direction without tracks if allowed to rest against a straight edge on one side. A friction wheel and disc arrangement driven by the electric motor allows change of speed in wide limits.

"Gewe" Automatic Cutting Torch

This machine cuts metal parts such as dies, cams, crankshafts and drop-forge tools

directly from the steel plate. It has two carriages. The upper carriage supports on one side an oxy-acetylene cutting torch, and on the opposite side the driving and the tracing system. A fiber template with the work outline grooved in it must be used. The speed can be regulated electrically by a rheostat or mechanically by changing the position of the friction wheel on the disk. The torch may be operated on either oxygen and hydrogen, or on oxygen and acetylene. The machine is made in two sizes having capacities of 12x12 in. and 24x24 in., respectively.

"Gewe" Automatic Shape Cutting Machine

In this machine the torch and tracer are rigidly connected and mounted on a double carriage system. An electric motor with reduction gear and friction wheel drives a friction disc carrying the tracing shaft, allowing ample speed regulation. Further speed regulation can be obtained with an electric rheostat. The patterns are made of soft material such as fibre plates. The driver runs on the inclined face of the pattern and presses the tracing roller or pin against the opposite side of the polished groove. When rotating it drags the tracer along the line of the groove. The tracer and driver work in two perpendicular planes and all possible vibrations are vertical, not affecting the smooth running of the tracer.

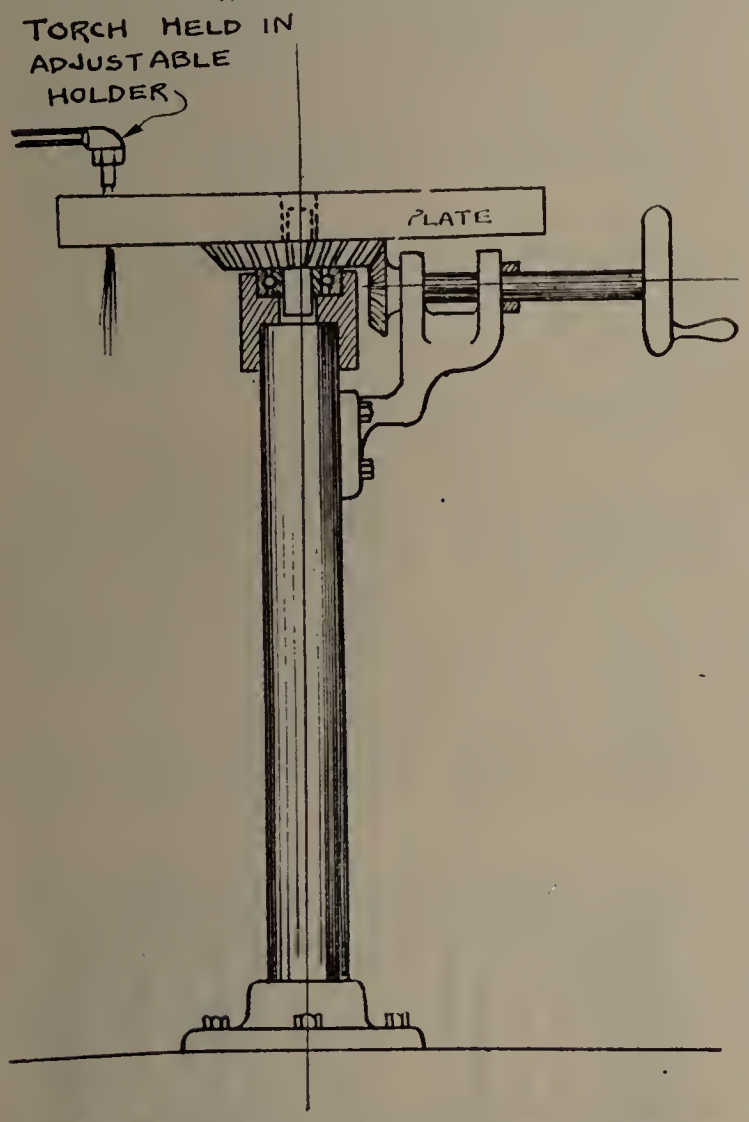


Fig. 15. A Revolving Stand for Cutting Circular Rings.

Figure 15 shows the construction of a cutting table for cutting circular steel rings, which consists of a substantial base carrying a movable platform controlled in its rotation by two bevel gears. The torch is mounted on a movable holder so that any diameter can be cut without complicated adjustments or measurements.

This points out only one simple case where individual initiative has resulted in a method of economically producing the required product. There are any number of such examples of welding and cutting applications where the welding engineer can be of service to the manufacturer in turning out simple, cheap devices which will eliminate manual labor and turn out a less costly and better product.

Cutting (with the Electric Arc)

See chapter on "Electric Arc Welding."

"Cut-Weld"

Trade name for cutting and welding torches. Made by Alexander Milburn Co., Baltimore, Md.

Cyc-Arc Welding*

A process whereby metal studs, rods, tubes, and the like can be automatically and directly welded or joined on to metal sheets, plates, bars, tubes, forgings, etc., by electrical means. It is called the Cyc-Arc owing to the particular cycle of operations required to effect the weld or joint.

The process is covered by patents and the apparatus, which is portable, consists of two main parts, viz., the container, which is completely enclosed in sheet iron and expanded metal, is divided into three compartments. One compartment contains (a) automatic timing and control apparatus, (b) marble connecting and regulating panel, (c) adjustable reactance, (d) non-inductive resistance, (e) carbon filament lamp resistance, another compartment contains the resistance coils for current regulation with supports and insulators, and the third compartment contains an electric contactor automatically operated.

The welding tool broadly consists of a solenoid, the plunger of which carries at its outer end a holder for the stud or other fitting to be welded. This solenoid is attached by means of supports and guides to a pair of magnets. These magnets are for retaining the tool in position when welding on to steel or iron surfaces. The solenoid with the stud holder is adjustable relative to the magnets in order to provide for the welding of different lengths of stud, tube or other fitting.

A simple arc-striking and limiting device is provided at the end of the solenoid by means of which a uniform and correct length of arc is ensured. A tumbler switch for closing and opening the magnet circuit and a bell push, by a single action of which each welding operation is effected, are provided.

The controller and welding tool are connected by two main cables, which are required for the control circuit and the main welding circuit.

The automatic timing and control of the arc during welding is the most important feature of the patents. The apparatus is designed for operation from a 60-100 volt direct current welding supply main. The normal current range is from 200 to 500 amperes, according to the size of the stud or other fitting to be welded. The actual energy consumed per weld is extremely small, the usual duration being about one second.

The apparatus will satisfactorily weld or join naval brass or manganese bronze studs up to ½ inch diameter on to brass, manganese bronze or iron or steel surfaces of practically any thickness, and also on to galvanized iron or steel. The operations necessary for making a weld are as follows: The stud or other fitting to be welded is first placed in the holder of the welding tool, and the latter is secured in the desired position by means of the magnets. The arc limiting device is then set, after which a single action of the bell-push starts the timing and control apparatus, thereby making the welds. By opening the tumbler switch the tool can be removed from the surface leaving the stud welded in position.

Once the apparatus has been set up for a particular size of stud or fitting its operation is practically automatic, and it can be worked by semi-skilled labor.

**By D. Richardson.*

"Cyclone"

Trade name for tool forges, brazing stands, etc. Made by Buffalo Dental Mfg. Co., Buffalo, N. Y.

Cylinders (Acetylene, Oxygen, etc.)

Acetylene

Dissolved Acetylene may be safely compressed in cylinders, but it is not safe, however, to compress free Acetylene to a pressure amounting to more than thirty pounds to the square inch. Acetylene dissolves freely in acetone (See "Acetone") which will absorb over twenty-four times its volume of acetylene at atmospheric pressure and ordinary temperature, and as the pressure rises, the absorptive capacity of the acetone increases. A given volume of acetone absorbs more than forty-eight volumes of Acetylene at two atmospheric pressure. When the cylinder is being charged, the acetone, as it absorbs the acetylene, swells and occupies more space, like a sponge which has been saturated with water and which is drying out. Therefore, if we were to charge an acetylene cylinder to at east 225 pounds to the square inch, the cylinder would be safe only so long as the full pressure of acetylene was maintained. If drained of acetylene the acetone would shrink, leaving a space for the collection of free acetylene, under very heavy pressure. The cylinder might explode under shock or rapid discharge of acetylene.

Acetylene cylinders are filled with a mixture which sometimes varies, but which in the main consists of charcoal, infusorial earth, asbestos, and some cement. This mixture, when compressed in the cylinder, becomes very porous and readily absorbs a large amount of acetone. The absorbent efficiency is from 75 to 80 per cent of the total bulk. The cylinders, under these conditions, may be charged to a pressure of 225 pounds per square inch, if they have been properly dried and baked. This is an operation, however, which should not be attempted by other than experienced engineers, accustomed to handling acetylene. This brief explanation of the construction of an acetylene cylinder is given only with the intention of informing the reader of the intricate construction of a safe acetylene cylinder and written in the hope that none but competent and properly equipped manufacturers will undertake to charge cylinders. Compressed acetylene may be had in tanks of varying capacity. See "Buyers' Index." It is rated, under atmospheric pressure and normal temperature, as weighing 14½ cubic feet per pound. A cylinder, for instance, weighing 200 pounds, when the stamped weight is 197 pounds, should contain three pounds of acetylene, or 14½ times three, which would be 43½ cubic feet of acetylene.

Oxygen

One hundred cubic feet of dry oxygen weighs approximately 8.9 pounds and one cubic foot weighs approximately 1.42 ounces. When filled a 200 cubic foot oxygen cylinder weighs about 142 pounds, or about 124 pounds empty. The contained oxygen in a charged cylinder weighs about 18 pounds. The amount of oxygen taken from a cylinder can be determined by the drop in pressure. In the case, for instance, of a 200 cubic foot cylinder, if the cylinder pressure is 1800 pounds per square inch the decrease in pressure per cubic foot taken out would amount to 1800 divided by 200. In other words, 9 cubic feet would have been withdrawn.

Hydrogen, Etc.

Hydrogen and oxygen cylinders do not differ, except that hydrogen cylinders have left hand valves, while oxygen cylinders have right hand valves.

Cylinders

The point is made clear in another part of this volume that it is very dangerous to use oil on oxygen cylinders. The danger lies in bringing the oil and oxygen together Therefore, it is equally dangerous to attempt to use cylinders which have contained gases made from petroleum products for carrying oxygen. Such cylinders are bound to contain a certain amount of oily deposit which would have to be completely removed before it would be possible to store oxygen in them without causing an explosion. One method of cleaning out this oily deposit which is very widely used and which is considered by competent gas engineers to be thoroughly safe is to wash them out with live steam at about 60 pounds pressure for five or ten minutes.

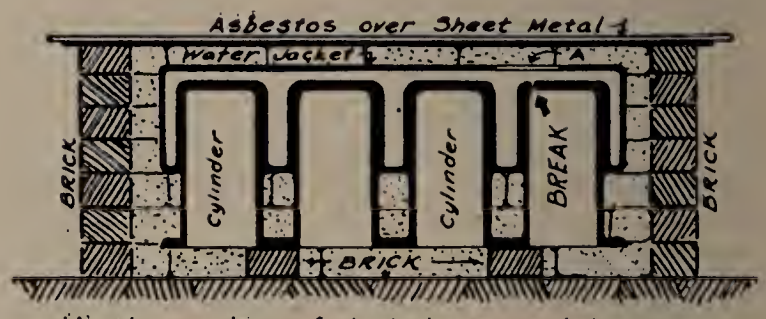
Cylinder Compression Heads

When the compression head of an automobile cylinder is cracked or broken, the best way to gain access to it so as to make a repair is to cut out a good sized piece from the water jacket so that the welding can be done from the outside. In beveling the work in the compression head, it is advisable not to carry the bevel all the way through but rather to depend upon reinforcing the weld on the outside to secure the necessary strength. As these sections are of uneven thickness, the weld should be started in the thicker portion of the metal. Test the cylinder with gasoline to make sure that the weld is oil tight before repairing the hole which has been cut in the water jacket.

The welding of cracked cylinder heads when cylinders are water jacketed sometimes proves rather difficult. The following description is based on the welding of a Cadillac block, but the method used would be the same on a six or an eight or even a single cylinder motor.

Once the break is located, drill a line of one-quarter inch holes, one-sixteenth inch apart in the water jacket, cutting out a piece large enough to enable the welder to work on the break. Use a cold chisel to break through the spaces between the holes and remove the piece of jacket, leaving the break exposed for welding.

Valve springs, pet cocks, etc., are then removed and the carbon block turned to the cylinder bore and inserted in cylinder to be repaired. Paint the cylinder walls with



'A' shows piece of Jacket removed to expose break. This piece welded in again

graphite and machine oil mixed to a consistency of thin paste to prevent peeling when the block is heated.

The block is then placed in the furnace in the upright position shown in illustration. If block is not in this positon when heated the chances favor the warping and egg shaped cylinders. The furnace is closed and the preheating torch lighted. For the first fifteen minutes a soft, mild flame is used, and the flame at all times directed so that it will not touch block. The block is then preheated until it is cherry red.

Then open the furnace as little as possible and weld the break, welding down to the carbon block inserted in the cylinder. When welding piece of jacket tack a welding rod to the section forming a handle to hold it in position. After bonding the section at three points melt off the rod and the piece is welded in place without difficulty.

The furnace is now closed and the block again preheated to a cherry red. The pre-heater is extinguished, furnace tightly closed and block permitted to cool slowly.

"Cylkote"

Trade name for flux coated nickel steel rod for electric welding scored cylinders and cracked water jackets. Made by Central Steel and Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, "Catalog Section."

—D—

"D-B"

Trade name for welding and cutting torches, regulators, supplies and accessories, acetylene generators, specially designed machines for automatic welding and cutting, etc. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York City. See Table of Contents, Catalog

"De Benardo"

Process of spot welding at points only. A carbon electrode is used. Patented Jan. 21st, 1888.

"Dee Bee"

Trade name for plate and cast aluminum flux. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Delmas"

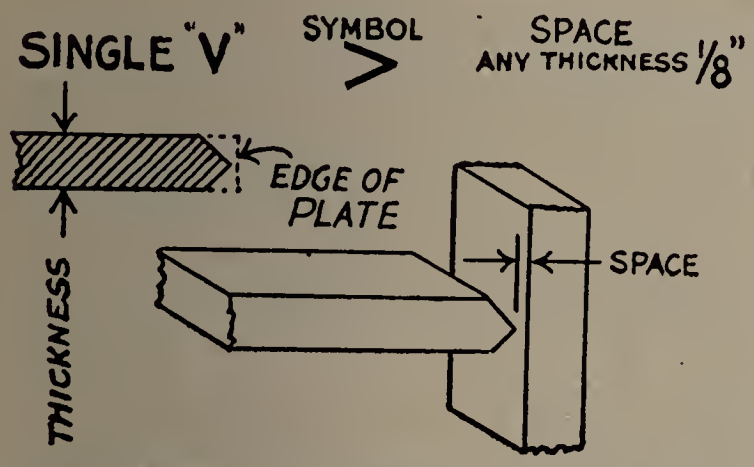
Trade name for welding compound. Sold by Century Tool and Metal Co., 180 N. Market St., Chicago, Ill.

Deoxidizing Agent

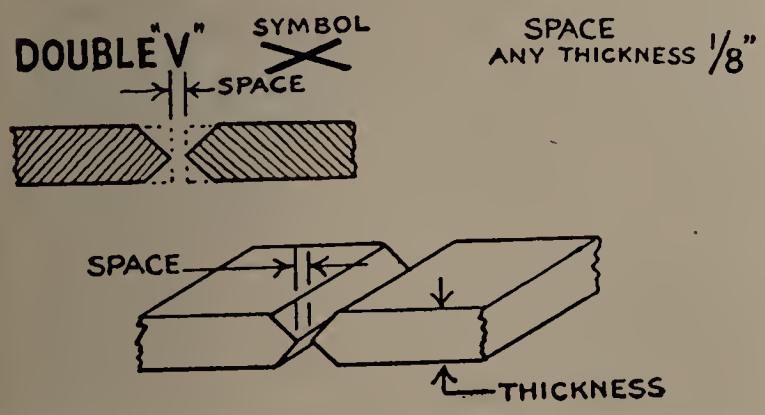
Chemical such as phosphorus used to get rid of oxygen and insure sound welds free from oxides and blowholes.

Design of Weld

SINGLE "V" is a term applied to the "edge finish" of a plate when this edge is



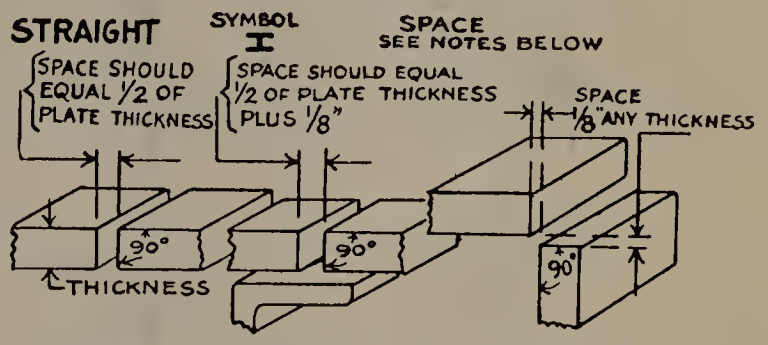
beveled from BOTH sides to an angle. the degrees of which are left to the designer. To be used when the "V" side of the plate is to be a maximum "strength" weld, with the plate setting vertically to the face of an adjoining member, and only when the



electrode can be applied from both sides of the work.

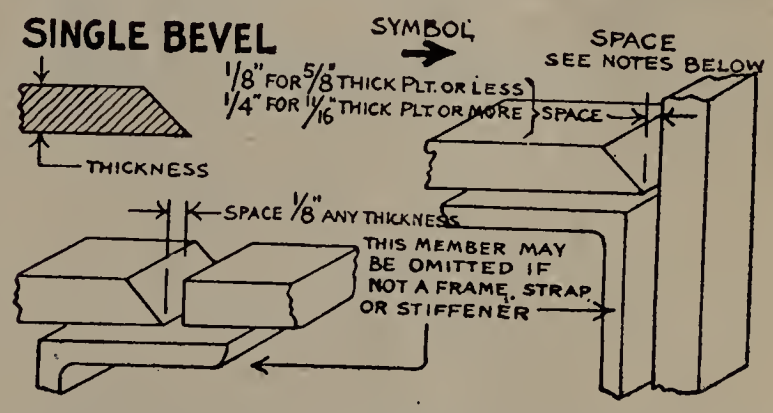
DOUBLE "V" is a term applied to the "edge finish" of two adjoining plates when the adjoining edges of both plates are beveled from BOTH sides to an angle, the degrees of which are left to the designer. To be used when the two plates are to be "butted" together along these two sides for a maximum "strength" weld. Only to be used when welding can be performed from both sides of the plate.

STRAIGHT is a term applied to the "edge finish" of a plate, when this edge is left in its crude or sheared state. To be used only where maximum strength is NOT



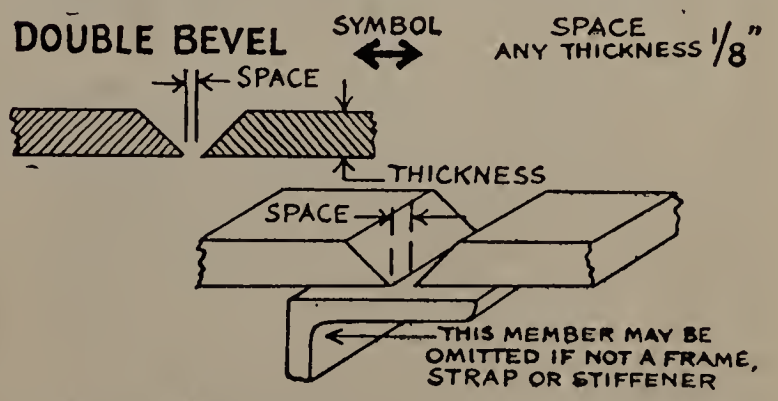
essential, or unless used in connection with strap, stiffener or frame, or where it is impossible to otherwise finish the edge. Also to be used for a "strength" weld. when edges of two plates set vertically to each other—as the edge of a box.

SINGLE BEVEL is a term applied to the edge finish of a plate, when this edge is beveled from ONE side only to an angle, the degrees of which are left to the designer.



To be used for "strength" welding, when the electrode can be applied from ONE side of the plate only, or where it is impossible to finish the adjoining welding surface.

DOUBLE BEVEL is a term applied to the edge finish of two adjoining plates, when the adjoining edges of both plates are beveled from ONE side only to an angle, the



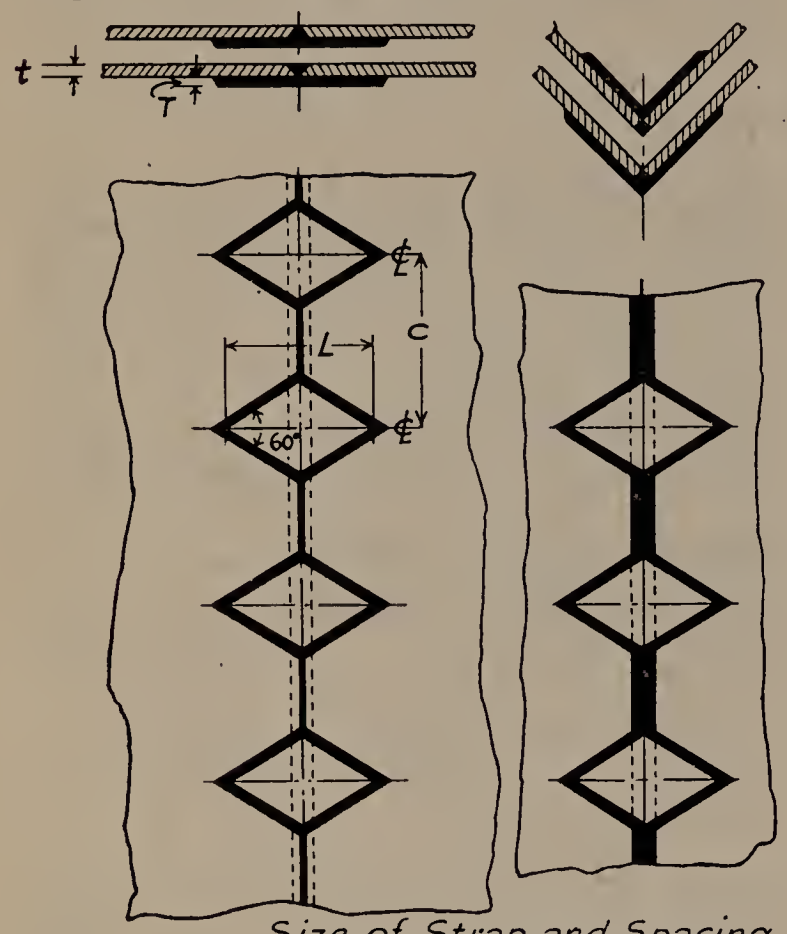
degrees of which are left to the designer. To be used where maximum strength is required, and where welding can be done on ONE side of the work only See "Bevel."

Dial

The graduated face of a pressure gauge. See Bourdon Tube.

Diamond Strap

A type of welded joint favored in some kinds of plate construction, such as shipyard work, as a substitute for the former bar strap design. See "Structural Steel."



Diamond Strap.

Diaphragm

The flexible partition in a regulator beneath the regulator spring. Also the partition in a high pressure gauge to protect the glass from being blown out when the Bourdon tube bursts. See Bourdon tube.

Die Castings*

As the repair of die castings appears to be a stumbling block in the welding shop, the operator should acquaint himself with the constituents of this peculiar alloy, and the possibilities of its repair.

The repair of these castings does not always present a practical aspect in the welding shop, as more time is required to make a repair of this nature than to make a weld of the same dimensions on other metals, due to special preparations having to be made and more time is spent in the repair operation.

These castings are used, wherever practical, in place of other metals, due to the fact that they can be manufactured and sold at a comparatively low price. However, the occasion often arises where time is the main factor, and the customer will gladly pay any reasonable price to have the repair made quickly.

It is a common occurrence for a die casting to be brought into the welding shop, where the operator is at a loss to name the metal, or to determine its character. Whereas, if he were able to explain intelligently the nature of the metal, and the approximate cost and strength of the repair, even though the customer would decide not to have the repair made, he would be more liable to place other intricate repairs in the welder's hands, feeling that he thoroughly understood the welding business.

**Written for The Welding Engineer by J. B. Diehl*

Composition of Die Castings

The words "die casting," are taken from the mechanical operation of "casting by the means of dies."

Any section or part that can be machined, can be die cast, as the accuracy will be within 0.001 inch on all dimensions whether inside or outside if the dies are made properly. This largely depends upon the judgment used in computing the shrinkage of the various metals in the composition.

Machine work is eliminated in die casting, owing to the above stated accuracy, and as the hot metal comes in contact with the dies, a skin is formed similar to that on a sand casting, which materially strengthens and adds to the wearing qualities of the metal.

From a metallurgical standpoint, die castings are considered superior to sand castings, being denser, stronger and with fewer blowholes if cast properly.

Die castings are easily distinguished from aluminum owing to the weight being considerably greater, while the color is several shades darker than aluminum.

It is possible for an inexperienced person to mistake Britannia metal for die cast metal owing to its weight, but as this is a white metal, having its use confined to the household it is seldom encountered, although it is well to understand the uses and nature of this alloy, which consists of 50% antimony, 25% bismuth and 25% tin.

The best die castings are made from alloys of the following metals: Lead, tin, zinc, antimony, aluminum and copper, although the majority of castings made now are mixtures of lead, tin, zinc and antimony.

The shrinkage varying from 0.002 to 0.007 of an inch per inch frequently depending upon the shape of the article.

Those having a zinc base will shrink considerably, while those of the tin base shrink very little. However, the operator need have no apprehension of shrinkage cracks in making repairs if a good filler material is used.

It is necessary to use an alloy having a tin base on carburetor parts or parts coming in contact with gasolene, or parts coming in contact with food products, as the lead or zinc alloys have a contaminating effect.

The three most prominent alloys in use are: The zinc base alloy containing 85% zinc, 8% tin, 4% copper, 3% aluminum melts at 852 degrees Fahrenheit. Owing to this being a cheap composition it is most commonly employed, but having very little tin in the mixture it cannot be called the best. This alloy will rapidly deteriorate with age, and is noticeably affected by the heat and cold.

The lead base alloy containing 80% lead, 15% antimony, 4% tin and 1% copper melts at about 550 degrees Fahrenheit, and is used where little wear and no strength are required. Owing to its weight, it is mostly rejected as a solution to auto parts manufacturing problems, and it is very brittle due to the large percentage of antimony.

The tin base alloy containing from 70 to 90% tin, 4 to 15% copper and a small percentage of antimony, depending upon the manufacturers ideas, melts at 675 degrees Fahrenheit and makes the best die castings available.

Method of Repairing

Die castings are very easily determined by the use of the welding torch. As the flame is applied, the skin will break into small particles and fly about, while a white smoke will arise due to the zinc vaporizing, the action being more pronounced on castings having a zinc base.

Where the metal is over ¼ inch thick, the fracture should be prepared as in welding for best results. The skin or oxide should be ground off for a space approximately ⅜ of an inch around the fracture, this being

essential, as the oxide melts at a higher temperature than the alloy and is troublesome if allowed to become mixed with the metal.

Owing to these parts being small as a rule, it is advisable to clamp them on a table to allow the operator free use of both hands. If the parts are of a hollow construction, or liable to drop out of alignment when melted, a form should be fastened beneath that section, and using a good aluminum solder as a filler rod. Care should be taken in selecting the solder that it does not contain a high percentage of zinc, as this is a troublesome factor in repairing die castings. The high percentage of zinc is used to make the melting point of the solder very low.

A soldering iron is used, having the surfaces filed clean of any other solder, and no acid is necessary to make the joint. A small iron can be used more advantageously than a large one, but as the small iron does not hold the heat long, it is often advisable to play the flame of the torch against it in such a manner as to supply the necessary heat. Care must be taken not to allow the flame to play on the casting, as it is impossible to make a repair of this nature with the welding torch owing to the melting point of the metal being low, and the danger of burning the zinc out of the alloy.

A small piece of solder should be layed on the fracture and worked in with the iron, while the heat is supplied from the torch.

It is not necessary to preheat die castings, also not advisable, on account of its low melting point and upon completion of the repair it will be found that the metal is quite hot throughout. The metal can be kept under control easily, and built up to the desired height, reinforcing wherever possible, care being exercised to remove all oxide.

If a soldering iron is not available a steel rod may be used, similar to those used in the puddle system for aluminum, heating it with the torch as explained with the soldering iron.

While this method is practical, it is not as good as the soldering iron owing to the fact that as the iron becomes red hot, oxide will form on the rod and incorporate in the alloy. This oxide should be removed to secure good results.

Water should be kept handy to dip the rod as it becomes too hot.

If a good filling material is used, it will be found upon finishing that the joint will stand up equal to any other section of the casting.

Dished Patch

See "Patching Tanks" in chapter on "Tank Welding."

Dissociation

Separation attended by the release of heat such as develops intensely in the combustion of acetylene with oxygen in the torch and produces the white hot cone having a temperature of about 6300° F. Dissociation of acetylene may result from over-pressure and shock.

Distortion

A state of being out of line, out of place or misshapen, warped, etc.

"Doelcam"

Trade name for preheating torches. Made by The Macleod Co., 2220 Bogen St., Cincinnati, Ohio.

Drawing the Arc

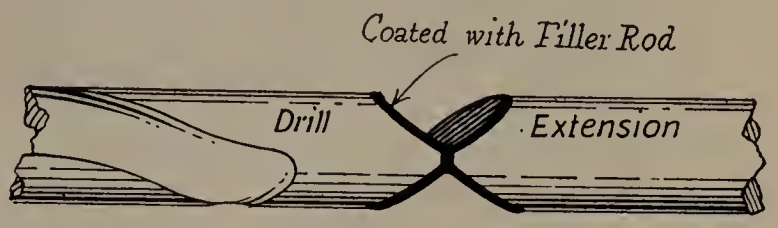
The first step in making a weld by the electric arc process. The electrode is brought into contact with the work, closing the circuit, and then quickly withdrawn a short distance. The current jumps across the gap and the arc is formed, bringing the work quickly to the welding heat. See chapter on "Electric Arc Welding."

Drift

A small tapered punch.

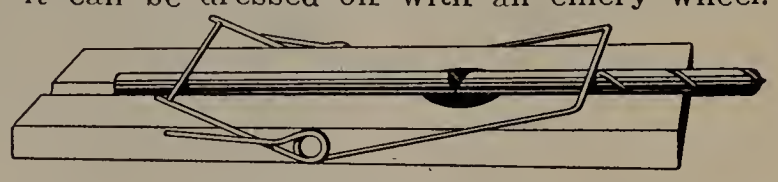
Drills

In welding extensions on small drills which are not subject to much strain the common practice is to line up the piece for the extension with the shank and make a butt weld. In the case of large drills the strain is normally greater it is advisable to prepare the parts as shown in the sketch. The



Welding Extension on Drill.

bevel is about forty-five degrees, with about an eighth of an inch on the end of each piece left flat. These ends are then built up with just enough nickel-steel to give a good coating. If any oxide or scale appears it can be dressed off with an emery wheel.



Jig for Welding Drills.

Then lay the pieces in a suitable jig, butt the ends together and weld with a nickel steel filler rod.

Driving Wheels

Figure A shows a driving wheel that was broken from the crankpin hole through the hub, and was welded with thermit and broken a second time.

In preparing this wheel for welding it was necessary to cut an opening of nine inches to rid the weld of the old thermit. This being all together too large a place to fill with the filler rod a block was made and scarfed to about a 45 degree on both sides and the hub of the wheel was scarfed to match, as shown in sketch. In placing this block in the opening it makes two welds, one on each side of the block. Both block and wheel hub were scarfed half way on each side, so that half of the weld was made from

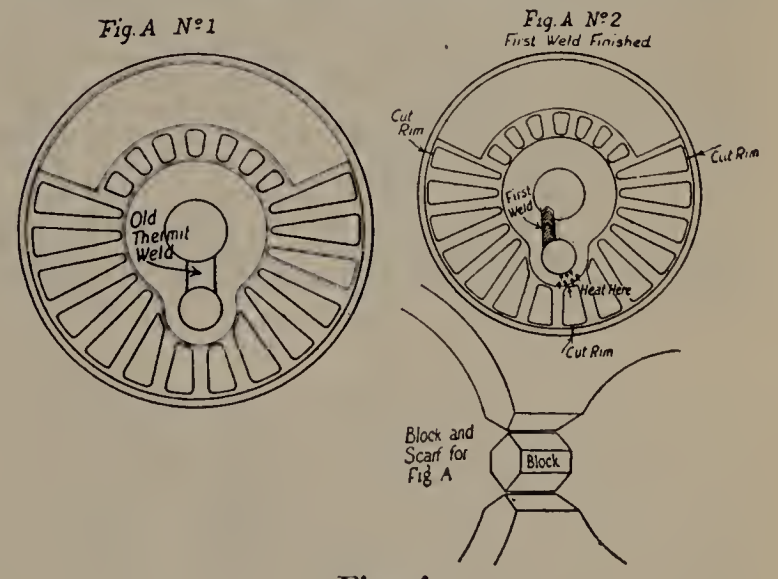
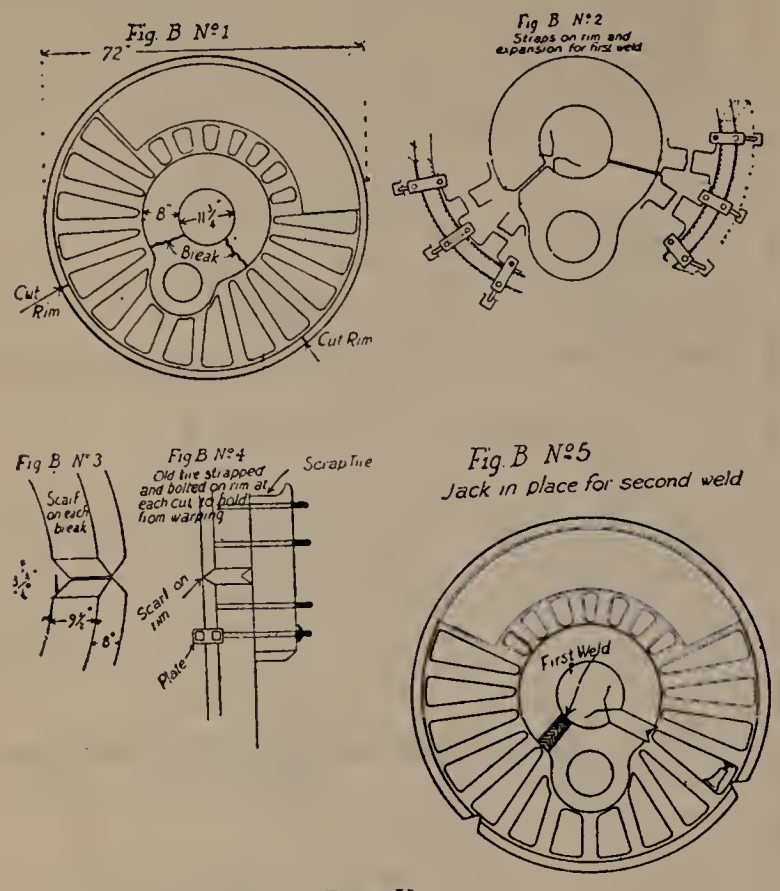


Fig. A.

opposite sides. Standing the wheel in an upright position an operator was started on the two sides of the weld at the same time and the first weld was made without paying any attention to expansion, as the block was free to contract, being loose on one side. After the first weld was made, the rim of the wheel was cut in three places, the center place being over the crankpin hole, leaving the wheel in an upright position, so that an operator could work on each side. Then heat was applied to the opposite side of the crankpin hole, directly across from the re-

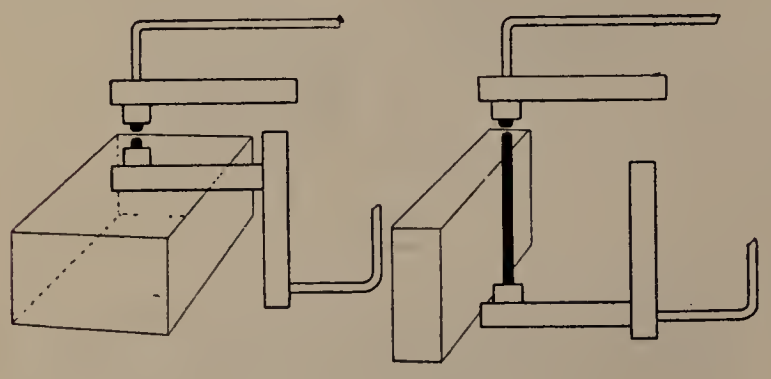
maining weld (as shown in Figure A, No. 2). Sufficient expansion can be gotten in this manner to allow for shrinkage on the



F g. B.

second weld, keeping the heated part hot while making the weld. It is not necessary to weld the openings in the rim, as they can be keyed. In welding a wheel with a clean break proceed the same as in making the second weld.

Figure B shows the same type of wheel broken in two places in the hub between the spokes. In preparing these welds, they were scarfed half way on each side, so that an operator could work on each side at the same time, or in the same manner that the welds were prepared in Figure A. The hub was trammed on both welds, so that the amount of expansion could be determined, being careful to put good punch marks well out from the weld, so that they will not be destroyed when the weld is being made. After the weld is made the amount of shrinkage in the weld can be determined. After the welds have been scarfed and trammed, cut the rim in two places, directly over the break in the hub, and between the same two spokes. This leaves the wheel in two pieces. Then take two pieces of old tire about five feet long and clamp to the rim over each cut. It is well to clamp these pieces in place before cutting the rim.



(a) Drop Horn (b)

Drop Horn

A specially constructed electrode holder for electric resistance spot welding machines, when it is desired to make spaced or overlapping spot welds along the seams of sheet metal boxes. The reach of the horns is sufficient to weld along the seam from top to bottom as in **a**. When it is desired to spot weld along the bottom seam the lower horn slides down and a longer electrode used as shown in **b**. In making weld **b** some power is lost through the electrical effect of the metal box around the lower electrode, so this type of work requires a machine of larger capacity than that used for spot welding flat sheets of the same gauge.

Ductile

Metal is said to be ductile when it can be drawn or stretched.

Ductility

Property possessed by metals and alloys that allows them to be drawn or stretched.

Duograph

Trade name for mechanically operated oxy-acetylene welding torch. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

Duplex Welding

See under "Spot Welding" in chapter on "Electric Resistance Welding."

Duralumin

An aluminum alloy containing copper, manganese and magnesium. Specific gravity, about 2.81. Melting point, 1210 Deg. F. Annealing temperature, 680 Deg. F. Castings show a tensile strength of 28,000 to 32,000 lbs. per sq. in., and 1% to 3% elongation; Brinell hardness 57, sceleroscope hardness 11. After heat treating tensile strength of 55,000 to 65,000 lbs. per sq. in. and 18% to 25% elongation; Brinell hardness, 93 to 100; sceleroscope hardness, 23 to 27.

The oxy-acetylene welding of "Duralumin" is apparently easy if a welding wire of the same alloy and a good aluminum flux are used, and the welds appear to be perfect. But if the welded portion is submitted to a bending test, failure takes place after a very slight deformation. The metal possesses no ductility in the welded zone and cracks develop rapidly if the joint is bent slightly. In other words, the weld has a high tensile strength, but its resistance to shock is extremely small.

Welding processes, therefore, should not be used when the parts are liable to bending action or shock. Pure aluminum welding wire can be used as a welding wire when welding "Duralumin" and as the two metals melt at practically the same temperature, no difficulty is experienced. Microscopic examination shows that the joining of the added metal and the "Duralumin" is perfect.

It is obvious that the use of a pure aluminum wire gives a very flexible added metal in the welded zone, but the strength of the weld is very low because the strength of pure aluminum is only about one-fourth that of "Duralumin." The metal in the neighborhood of the parts melted by the torch has the characteristic fragile structure of aluminum and the failure of such a weld from shock inevitably takes place where the added metal joins the base metal.

Dur-Iron

An iron chemically treated to make it acid proof. It is very brittle, hard to chip, and the expansion is several times that of cast iron. In welding this metal a good quality cast iron filler rod should be used and the work should be thoroughly preheated and cooled slowly.

—E—

"Easyflow"
Trade name for cast iron welding rods and fluxes. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Easy Way"
Trade name for welding trucks. Made by M. Desmond Mfg. Co., Edwardsville, Ill.

"Ebony"
Trade name for a fabric covered welding and cutting hose. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Economy"
Trade name for welding and cutting torches, supplies and accessories, acetylene generators, etc. Made by Economy Welding Machine Co., 20th and Central Sts., Kansas City, Mo.

Edge Weld
The joining of two parallel pieces by welding the edges together.

Elastic Limit
The maximum load a metal will sustain before it begins to stretch. See Elongation.

Electric Annealing
See "Annealing, Electric."

Electric Brazing
See "Brazing, Production Work."

Electric Blowpipe
See "Zerner Process of Electric Welding."

Electric Soldering
See "Soldering."

Electric Tempering
A useful application of the electric butt welding machine. Small pieces that need tempering can be clamped between the jaws of a butt welder and quickly heated by turning on the current, then quenched in water or oil.

Electric Welding
The joining of metals by the application of the heat in an electric circuit concentrated at the point to be welded. See chapters on "Electric Arc Welding" and "Electric Resistance Welding."

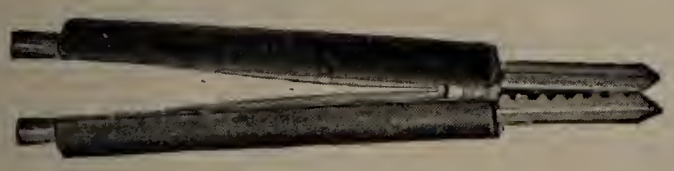
Electrode
Filling metal used in metallic arc welding.

Electric Welding Research Council
See under "Associations."

Electrodes
In electric arc welding: The conductors by which the current enters and leaves the two ends of the arc.

In electric resistance spot welding: The conductors by which the current enters and leaves the spot on the work.

In electrolytic oxygen-hydrogen generation: The conductors by which the current enters and leaves the water, which is decomposed by the passage of the current.



Electrode Holder

Electrode Holder
Device used in electric arc welding to hold the carbon or metallic electrode. It is provided with an insulated handle. The illustration shows a common type of electrode holder.

"Electrolabs"
Trade name for oxygen and hydrogen electrolytic generating plants. Made by The Electrolabs Co., 2635 Penn Ave., Pittsburgh, Pa.

Electrolyte
Chemical (caustic soda or potash) in cells of electrolytic oxygen and hydrogen generator, which acts as a conductor.

Electrolytic Oxygen and Hydrogen
See Oxygen.

Electromagnetic Weld
See under "Electro-Percussive Welding" in chapter on "Electric Resistance Welding."

Electromotive Force
Electrical pressure. The unit of measure of electromotive force is the volt.

Electro-negative
Condition of metal deposited by slag covered electrode, which prevents corrosion.

Electro-positive
Condition of local area of metal relative to adjacent areas setting up electrolytic action and corrosion.

Electrostatic Weld
See under "Electro-Percussive Welding" in chapter on "Electric Resistance Welding."

"Elecweld"
Trade name for steel wire for electric arc welding. Made by Steel Sales Corporation, Adams and Jefferson Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Ellipsograph"
Trade name for mechanically operated oxy-acetylene cutting torch. Made by Shawver Co., Springfield, Ohio.

Elongation
The stretch of metals when pulled in a testing machine. Usually measured with reference to the length of the specimen.

Endothermic
Relates to the absorption of heat. Acetylene gas, for instance, is an endothermic substance, heat being absorbed in the reaction of calcium carbide and water.

Equi-axed
This term is applied to the grains of a metal or alloy after solidification and to grains of metals or alloys which have been strained and allowed by a process of suitable annealing to assume a condition approaching crystalline equilibrium.

Equi-axed Grain
An unstrained grain which has approximately equal dimensions in all directions. This term is practically restricted to unstrained metals.

"Essentialite"
Trade name for a glass for electric arc welding helmets. Made by the Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. See Table of Contents, Catalog Section.

Etching
A process of preparing welds for examination and test. File a top to bottom section of the weld with a coarse file, followed by finer files. File marks should be across previous file marks. After filing polish surface with emery paper, starting with No. 1 and end with No. 000, so as to obtain a high polish. Do not touch polished surface with hands and keep free from grease or dirt. Then apply the following solution with a brush: For iron and steel one part nitric acid and two parts water.

This solution immediately attacks the oxide, exposing any adhesion, blowholes, lack of metal, etc. Wash the surface etched with clean water and dry with alcohol. If the test is to be preserved cover it with a layer of transparent varnish.

For copper, brasses and bronzes use a solution composed of 25 parts nitric acid and 75 parts water. Treat the test piece as before. For aluminum use a solution con-

sisting of 10 parts hydrochloric acid and 90 parts water.

The maximum time for the solution to act in any of the above cases is fifteen minutes. Great care must be used to keep the polished surface clean, as oil or dirt will prevent action of the solution. See Testing Welds.

Etching Reagent

A substance or reagent used to reveal the structure of a metal or alloy causing a difference in the appearance of different constituent parts or different grains. This substance is usually a solution of the reagent in water, acid or alkali, but etching may in some cases be brought out by a differential oxidation produced by "heat tinting."

Eutectic

See Cast Iron, Hard Spots In.

Even Arc

An arc that maintains the same approximate length and the same temperature.

"Everett"

Trade name for cast iron flux. Made by Bierman-Everett Foundry Co., Irvington, N. J.

"Eveready"

Trade name for oxy-acetylene welding and cutting equipment. Made by Oxweld Acetylene Company, Newark, N. J. See Table of Contents, Catalog Section.

"Everstay"

Trade name for metal alloy for repairing scored cylinders. The name is also used for a flux to be used with this alloy. Made by The Ever-Stay Metal Co., 1501 Jackson St., Omaha, Neb.

"Ever-Stick"

Trade name for alloy for repairing scored cylinders. Made by Great Western Smelting & Refining Co., 600 W. 41st St., Chicago, Ill.

Expansion

The increase in the dimensions of metals, due to heat. A bar of iron expands as it is heated and contracts when cooling, both being attended by great force. Expansion in length, breadth and thickness is governed by the rise in temperature. Contraction is therefore regulated by the fall in temperature. Expansion rates of various metals differ. A copper bar one foot long expands one-tenth of an inch per 1000 degrees F. per foot. A grey iron bar of the same size would expand a little over one-tenth of an inch per foot when heated to 1500 degrees F., the expansion rate being 0.068 inch per foot 1000 degrees rise in temperature. The expansion of aluminum is 0.148 inch per foot for each 1000 degrees F. Aluminum should never be preheated to more than 600 to 800 degrees and when heated an aluminum casting should be handled very carefully, as it is weak and brittle. Expansion is taken care of usually by proper preheating.

One of the greatest difficulties to be contended with in welding is the control of expansion and contraction due to differences in temperature of different parts of the piece welded. In the case of ductile materials, like iron and steel, warping, distortion or buckling will inevitably take place if expansion and contraction are not properly allowed for. In non-ductile materials, such as cast iron or materials whose strength are low when near the melting point, as for example aluminum, aluminum alloys and copper, the strains produced may cause the metal to crack or fracture. Further, in many cases although distortion or fracture have not taken place the expansion and contraction effects have produced serious internal strains, which only require a slight addition to exceed the strength of the metal and thus produce failure. It is for this reason that many welded articles which appear to have been successfully welded prove to be failures shortly after being put back into service.

It is necessary to repeat over and over again to welders that it is useless to attempt to arrest or control by force the expansion of metals raised to a high temperature and which return more or less to their original dimensions when the heat, which has produced the expansion, diminishes and finally disappears. In other words, the forces of expansion and contraction are irresistible and if attempts are made to control them by force—the use of clamps, jigs, etc.—distortion, serious internal strains, or failures will result.

When metallic bodies are heated they expand in every direction; and conversely a decrease in temperature causes the bodies to contract and the volume and linear dimensions decrease. In many practical cases we are only concerned with the increase in length. Increase in length is referred to as "linear" expansion, and increase in volume is called "cubical" expansion. Metals are very susceptible to this change in volume, each metal, for a definite rise of temperature, expanding a known amount. It is convenient to calculate the amount of expansion to be expected from a rod of the metal of unit length when it is raised through one degree of temperature. This amount is called the "coefficient of linear expansion."

Increase in length produced by Rise of Temperature

Original length × Rise of Temperature.

In dealing with cubical expansion the word "volume" is substituted for length.

For calculating the deformation brought about by contraction effects it is useful to know what contraction usually takes place when certain metals have been welded and the line of welding subsequently cools down. The following are the usual shrinkage allowances for each foot of length:

Cast Iron—thin material	= $\frac{1}{16}$ inch
Cast Iron—thick material	= $\frac{3}{32}$ inch
Steel	= $\frac{1}{4}$ inch
Copper	= $\frac{3}{16}$ inch
Malleable Iron	= $\frac{1}{8}$ inch
Aluminum	= $\frac{1}{16}$ inch
Brass	= $\frac{3}{16}$ inch
Lead	= $\frac{5}{16}$ inch

See also under "Preheating."

Expansion—Coefficient of

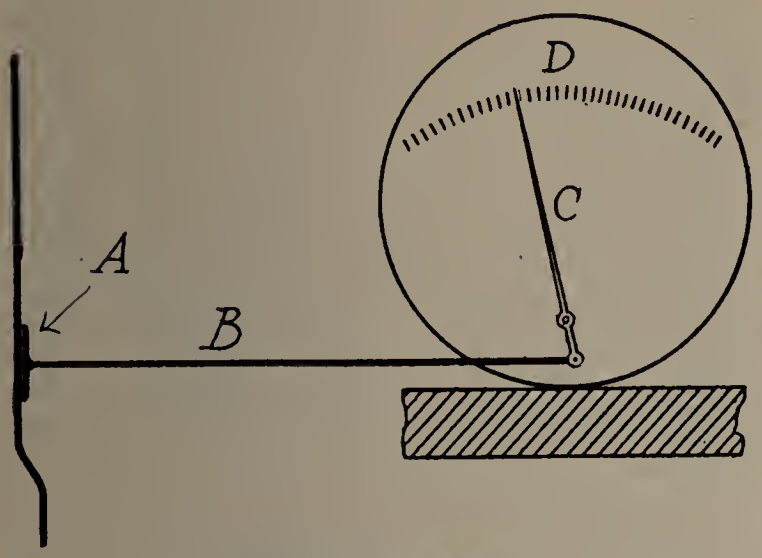
The increase for each inch of metal for each degree of temperature increase:

	Melting Point	Conductivity with silver 100	Expansion per foot each 100F increase
Wrought Iron	2700	12	.007
Mild Steel	2650	11	.008
Hard Steel	2550	10	.008
Grey Cast Iron	2200	10	.006
Nickel	2600	—	.008
Copper	1900	74	.0106
Brass	1750	—	.011
Bronze	1650	—	.012
Aluminum	1200	32	.015
Zinc	850	20	.017
Lead	650	8	.018
Tin	450	15	.016

Expansion Gauge

A device for recording distortion of metal parts due to expansion. The illustration shows the working principle. Disc (a) rests against the work. If the piece expands the rod (b) displaces the needle (c) and the displacement can be noted on the scale (d). If two or more of these gauges are placed at different points on the metal that is being heated, the different readings on the scales will show clearly where expansion

or distortion is the greatest, and a change in the heating arrangement can be made so as to prevent unequal distortion and thereby preserve alignment.



Expansion Gauge.

Eye Protection*

Radiation from an intensely heated solid or vapor may be divided under the three headings:

(1) Invisible infra-red rays.
(2) Visible light rays.
(3) Invisible ultra-violet rays.

There is no clear line of demarcation between these divisions, as they melt gradually one into the other like the colors of the visible spectrum. When the heated matter is solid, such as the filament of an incandescent lamp, the visible spectrum is usually continuous, that is, without lines or bands; but when it is in the form of a gas or vapor, as in welding operations, the spectrum is divided up into bands or is crossed by lines which are characteristic of the element heated.

The intense glare emitted in the process of arc welding consists of a combination of all these rays, and special safety devices are required to protect the operator from their harmful effects.

For welding with acetylene and for light electric welding, it is necessary only to protect the eyes with goggles fitted with suitable colored glasses. Hand shields are made for medium weight electric welding work, which can be done with one hand; and it serves the double purpose of protecting the eyes of the operator and also shielding his face from the heat rays and the ultra-violet radiation, which would otherwise cause a severe sunburn effect.

For heavy electric welding, which requires the use of both hands, it is common practice for the operator to protect his eyes and neck with a helmet fitted with a round or rectangular window of safety glass. These helmets are usually made of some strong light material such as vulcanized fiber and are designed so that they can be slipped on and off easily, the weight resting on the shoulders of the operator.

There are a great many different kinds of special safety glasses on the market, and many combinations of ordinary colored glass are also in common use, so a brief discussion of this very important subject is in order.

It is well known that the normal human eye shows considerable chromatic aberration towards the red and blue-violet ends of the spectrum and that this defect is completely corrected in regard to the middle colors. It, therefore, naturally follows that a much clearer definition of an object is obtained by combinations of yellow-green light than by red alone, or especially by blue or violet light alone. The eye is also more sensitive to the yellow and green rays than it is to the red and blue rays; or in other words, yellow-green light has the highest luminous efficiency. This may easily be verified by looking at a sunlit landscape or fleecy clouds in a blue sky through plates of different colored glass. A glass of a light amber color or amber slightly tinted with green will clearly bring out details that are hardly observable without the glass, and which will be obscured entirely by a blue or violet glass. It is therefore obvious that in order to obtain **the clearest definition or visibility with the least amount of glare,** the selection of the **color tint** in safety glasses should properly be decided by an expert; but the **depth of tint** or, in other words, the **amount of obscuration** may be determined best by the operator himself, owing to the individual difference in visual acuity which will permit one man to see clearly through a glass that would be too dark for another man.

A proper selection of color tints can be assisted by spectroscopic examination.

Having considered briefly the best means for toning down the glaring and flickering visible light produced in the welding process, we may now direct some attention to the infra-red and ultra-violet rays, which always accompany the visible glare.

When the invisible infra-red rays encounter any material which they cannot penetrate, or which is opaque to them, they are absorbed and are changed into heat. Hence, they are frequently termed heat rays.

It is, therefore, very necessary to guard the eyes from these rays; and although they are absorbed to a certain extent by ordinary colored glass, this is not sufficient protection against any intense source. There are, however, several kinds of glass, which although fairly transparent to visible light, are wonderfully efficient in absorbing heat.

Table 1 indicates roughly the percentage of heat rays transmitted by various colored glasses of given thickness. The source of heat used was a 200-watt, gas filled Mazda lamp operating at a temperature of about 2400 deg. C. Although the figures are substantially correct for the samples tested, they would necessarily vary somewhat for other samples of different thickness and degrees of coloration, so that they can be taken only as a general guide for comparative purposes.

TABLE 1

Kind of Glass	Thickness In Inches	Per Cent Heat Rays Transmitted
Clear white mica	0.004	81
Clear window glass	0.102	74
Flashed ruby	0.097	69
Belgium pot yellow	0.126	50
Cobalt blue	0.093	43
Emerald green	0.100	36
Dark mica	0.007	15
Corning G-124J lt. gr. glass	0.095	10

We now come to the invisible ultra-violet rays, which are principally to be feared not only because they are invisible, but because, as previously stated, we have no organ or sense for detecting them, and we can only trace their existence by their effects. In all cases, however, when we are forewarned of their presence, they are very easily shielded, for there are only a few substances which are transparent both to visible light and to ultra-violet radiation. Foremost among these latter substances, because it is most common, is clear natural quartz or rock

By W. S. Andrews in the General Electric Review.

crystal, from which the so-called "pebble" spectacle lenses are made. Fluorite and selenite are also transparent to ultra-violet rays, but these crystalline minerals are rare and not in common use. However, a moderate thickness of ordinary clear glass, sheets of clear or amber mica, and of clear or colored celluloid or gelatine are opaque to these dangerous rays. As a case in point, it is well known that the mercury vapor lamp, when made with a quartz tube, is an exceedingly dangerous light to the eye, being a prolific source of ultra-violet radiation, so that when it is used for illumination, it is always carefully enclosed in an outer globe of glass. When the mercury vapor lamp, however, is made with a clear glass tube it is a harmless, if not very agreeable, source of light, because the outer tube of clear glass is opaque to the ultra-violet rays that are generated abundantly within it by the highly luminescent mercury vapor.

When operating with a source of light that is known to be rich in ultra-violet rays, such as the iron arc in welding operations, it is not sufficient to guard the eyes with ordinary spectacles because these invisible rays are capable of reflection, just the same as visible light, and injury may easily ensue from slanting reflections reaching the eyes behind the spectacle lenses. Goggles that fit closely around the eyes are the only sure protection in such cases. Also when using a hand shield, the shield should be held close against the face and not several inches away from it.

It may here be mentioned that the invisible ultra-violet rays, when they are not masked or overpowered by intense visible light, produce the curious visible effect termed "fluorescence" in many natural and artificial compounds. That is, these rays cause certain compounds to shine with various bright characteristic colors, when by visible light alone they may appear pure white or of some weak neutral tint. Thus, natural willemite, or zinc silicate, from certain localities (which may also be made artificially) shows a bright green color under the light from a disruptive spark between iron terminals; whereas this compound is white or nearly so by visible light. Also, all compounds of salicylic acid, such as the sodium salicylate tablets which may be bought at any drug store, are pure white when seen by visible light, but show a beautiful blue fluorescence under ultra-violet rays. Many other chemical compounds could be mentioned which possess this curious property, but the above substances will suffice to illustrate the effect of fluorescence produced by ultra-violet rays, and by which these rays may be thereby detected. It must, however, be noted that these substances will only show their fluorescent colors very faintly when viewed by the light of the low-tension iron arc used in welding, because the intense visible light of this arc will overpower the weaker effect of the invisible ultra-violet rays. The true beauty of fluorescent colors can only be seen under a high-tension disruptive discharge between iron terminals, the visible light in this case being weak while the ultra-violet rays are comparatively intense.

Summarizing the effective means for eye protection against the various harmful radiations that are particularly associated with welding operations:

(1) The intense glare and flickering of the visible rays should be softened and toned down by suitably colored glasses, selected by an expert and having a depth of coloration which shows **the clearest definition combined with sufficient obscuration or glare,** which last feature can be best determined by the individual operator.

(2) When infra-red rays are present to a dangerous degree, a tested heat-absorbing or heat-reflecting glass should be employed, either in combination with a suitable dark colored glass, when glaring visible light is present, or by itself in cases where the visible rays are not injuriously intense.

(3) In guarding the eye from the dangerous ultra-violet rays, it must be carefully noted that "pebble" lenses are made from clear quartz or natural rock crystal, and this material being transparent to these rays offers **no protection** against their harmful features. On the other hand, ordinary clear glass is a protection against these rays when they are not very intense, but dark-amber or dark-amber-green glasses are absolutely protective. Glasses showing blue or violet tints should be avoided, excepting in certain combinations wherein they may be used to obscure other colors.

"E-Z"

Trade name for welding fluxes. Made by Anti-Borax Compound Co., Ft. Wayne, Ind. See Table of Contents, Catalog Section.

—F—

Fade-away Weld
See Sheet Metal Welding.

Fahrenheit and Centigrade Scales
See Table of Contents for Tables and Scales.

Fay Welding Process

A special adaptation of the alternating current electric arc welding process. Also known as the Seamweld system. The electrodes are covered with a patented coating which is said to give sufficient burning power so that no preparation of the joints is necessary. On sheets up to ⅛-inch the edges are butted together, and on larger stock the square edges are left a small distance apart and the center of the arc is made to coincide with the center of the gap, the gap being about 1/16-inch on ⅛-inch plate and increasing gradually to about ¼-inch on ½-inch plate. It is also necessary that a chill or backing be provided directly under the seam for the purpose of cooling the molten metal and preventing the formation of blowholes. The chills are usually made of copper. Sometimes, however, the stock is lapped under and forms its own chill. See under "Seamweld."

"Federal"
Trade name for Federal Tool & Alloy Steel Corporation, Woolworth Bldg., New York, N. Y.

"Federal"
Trade name for electric spot welding machines. Made by Federal Machine & Welder Co., Warren, Ohio.

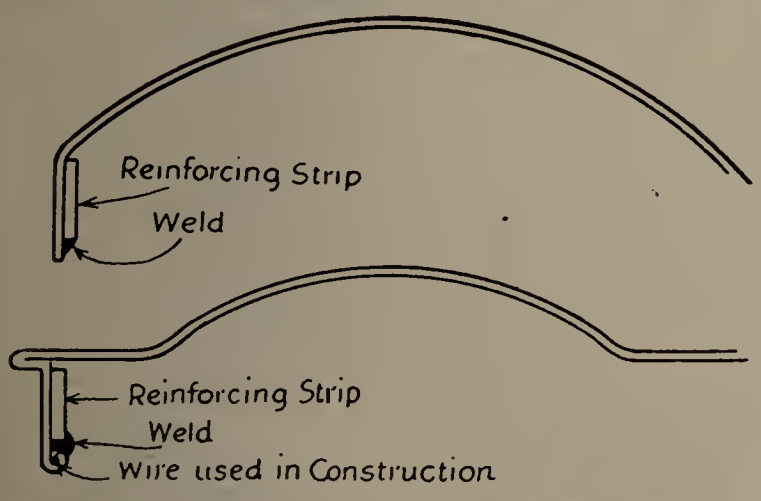
"Federal"

Trade name for welding and cutting torches, oxygen and acetylene regulators and welding supplies. Made by Federal Brass Works, 31st St. and Kedzie Ave., Chicago, Illinois.

Feeding Disc
The revolving plate on which the carbide drops from the hopper of an acetylene generator when feeding.

Fender Welding

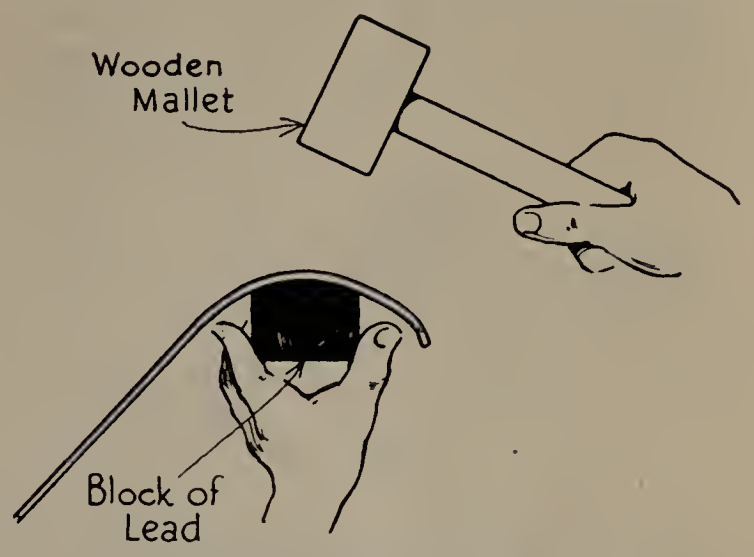
Use a light welding torch, capable of producing a small and very soft neutral flame, and a one-sixteenth or five thirty-seconds inch welding wire, which is soft, clean and free from carbon. Practice on scrap sheet metal, the same thickness as the ordinary fender. Hold the flame in contact with the



Typical Fender Constructions and Methods of Reinforcing

metal until it just starts to melt. Then advance the flame along the surface, just melting the metal and passing on.

It is extremely important that the flame be soft. Use as little filler rod as possible. If the break is a long one, it should be spread slightly to allow for the contraction which will draw the edges together and cause them to overlap as the welding progresses. It is also practical to tack the edges together every two or three inches before starting to weld. Always start from a closed end of a crack and work towards the open. Fenders usually break on the outer edge, therefore, it is generally considered that the original metal at the point



Removing Buckles and Dents

of break was not strong enough, and that the weld will not hold unless it is reinforced. Fig. 1 shows two common forms of fender construction and methods of reinforcing. By taking a small strip, about twice the thickness of the metal, and from three-quarters of an inch to an inch wide, and placing it just inside of the outer edge and welding it along the lower edge, the fender is made twice as strong at the point where so much strain comes. This reinforcing strip can be held in place by tacking it to the end of an extra filler rod, which may be used as a handle. It is only necessary to weld it along the lower edge. In case of Aluminum Fenders, use a good sheet of aluminum flux and a filler rod, made by cutting strips of thin sheet aluminum. Remove buckles by using a block of lead and a wooden mallet as illustrated in Fig. 2. Dress off the top of the weld with a portable grinder and finish with a good quick-drying stove-pipe enamel. See "Sheet Metal."

Ferrite

The iron in steel is called ferrite, to distinguish it from the usual terms "iron" or "steel," which include the whole mass. See "Testing Welds."

"Ferronite"

Trade name for steel welding rods. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Ferro-titanium

A deoxidizing agent. Also used in the manufacture of alloy steels.

Fibrous Welds

A poorly executed, porous weld, containing blow holes, craters, etc.

Filler Rod

The rod or wire which is added to the weld. Also referred to as Adding Material and Welding Rod. See "Welding Rods."

Fillet Weld

A fillet weld is one in which some fixture or member is welded to the face of a plate, by welding along the vertical edge of the fixture or member (see "welds" shown and marked "A" in Figure 1). The welding material is applied in the corner thus formed and finished at an angle of forty-five degrees to the plate.

Figure 2 shows a fixture attached to a plate by means of a composite weld of not less than three layers with a reinforced finish. The fixture being placed vertically,

necessitates a combination of flat, vertical and overhead welding in the course of its

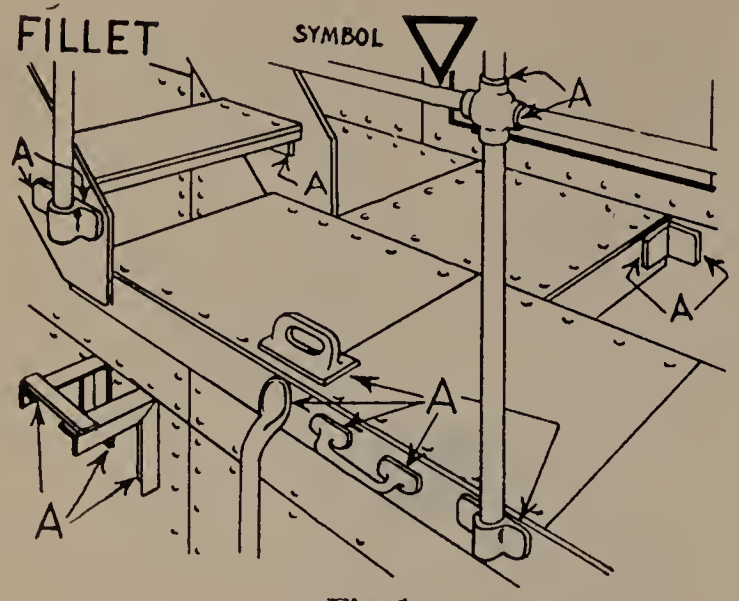


Fig. 1.

erection. Although a fixture of this kind would probably never be required to be watertight, the composite symbol is shown simply as a possibility of a combination.

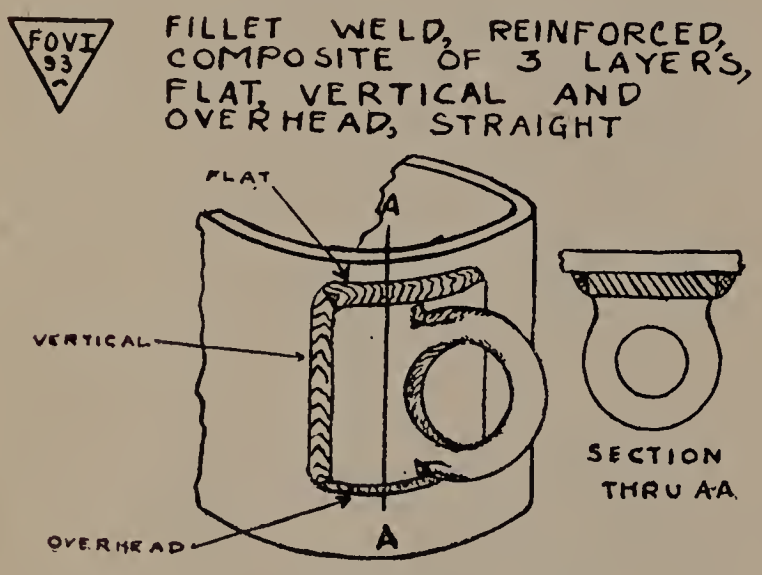


Fig. 2.

Figure 3 represents a fixture attached to a plate by a strength fillet weld of not less than three layers, finished flush. The edges of the fixture are left in their natural state, and the welding material applied in the cor-

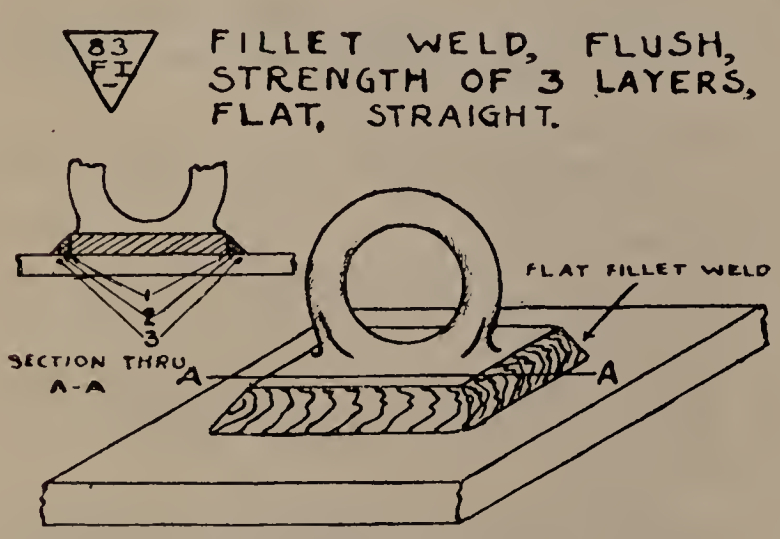


Fig. 3.

ner formed by the vertical edge of the fixture in contact with the face of the plate.

Since the cross section of the deposit is not equal to the cross section of the original metal, it is necessary to have an absolutely rigid joint between the original sections before the fillet weld is applied. If this is not done, the weld may be called upon to stand some of the stresses which are supposed to be taken up by other parts of the structure. The fillet weld when properly made consists of a single bead deposited so that it penetrates equally into both members. If the arc is directed slightly toward the vertical face of the joint, the influence of gravity will be somewhat counteracted, and the proper deposit will be secured. There are two ways to make a heavy fillet weld. The most favored one is by first laying a single bead in the crater and then filling in on top of it with additional beads. Since one of the most important applications of this weld is welding of boiler tubes after they have been rolled and beaded, it should be noted that any oil which remains on a work after rolling and beading, must be burnt away before the welding is done.

Filling Metal

Metal added during the welding process to form part of the weld.

Filling Rod

Filling metal used in carbon electrode arc welding.

Filter

A device for removing dust and floating impurities from acetylene gas.

Fire Box Welding

An eastern railroad which has its welding procedure very well standardized, has adopted the following procedure:

In welding complete fire boxes, use a butt weld. The sheets should be beveled on the inside and set in place on the mudring, then tacked in the water space. All fireboxes are welded on the floor. Starting in the center of the flue sheet at the bottom, the weld is made up to the ear or lap. The fire box is then turned over and the welding continues from the center of the crown sheet to the mud-ring, giving ⅛-inch re-enforcing. After completing the weld on this side, the box is again turned and with a round nose chisel, a groove about $\frac{3}{16}$-inch deep is cut in the seam in order to get all the scale and dirt off. This groove is then re-enforced with ⅛-inch or one inch layer of welding metal. On the flue sheet put ½-inch by three inches round mild steel bars and weld around it. On the throat sheet five bars are used in the same way. The reason for putting on these bars is to stiffen the flue sheet when the flues are rolled. In welding half throat sheets and backheads, the sheets are beveled the same as the fire box side and welded before rivets are put in, giving about $\frac{3}{16}$-inch by ⅛-inch re-enforcing.

In welding mud-ring corners put a fillet weld on the inside through plug holes and re-enforce ½ by 1¼-inch by 12 inches on the outside.

In welding ½ fire boxes use a staggered seam, starting the cut back from the throat sheet two staybolts, then up one staybolt. The seam then goes back two staybolts, down one, back two and so the length of the fire box. By staggering seams expansion and contraction is scattered in all directions.

In welding patches in fire boxes use an oval patch so there will be no sharp corners. The patch has a $\frac{3}{16}$-inch radius so that there will not be any strain after the weld has been made. In applying the patch after the top and sides have been tacked on, the weld is begun at one end of the patch and continued across the top. The ends of the patch are welded from the top down, first welding about three inches on one end and then the same amount on the other until the ends are completely welded. The patch welding is then completed by beginning at one end at the bottom and continuing to the other end, and re-enforcing about $\frac{3}{16}$-inch. By welding this way the heat from the welding travels up into the patch and the contraction will straighten out the patch.

In welding cracks in fire boxes where they are over four inches long, the crack is V'd out to a feather edge. The welding is begun three inches from the top and the weld continues to the top. Welding is then begun about three inches further down and continues upward as before and so on until the crack is filled up. The next step is to take a welding hammer and bob up the welding material that has been applied and put on $\frac{3}{16}$-inch re-enforcing.

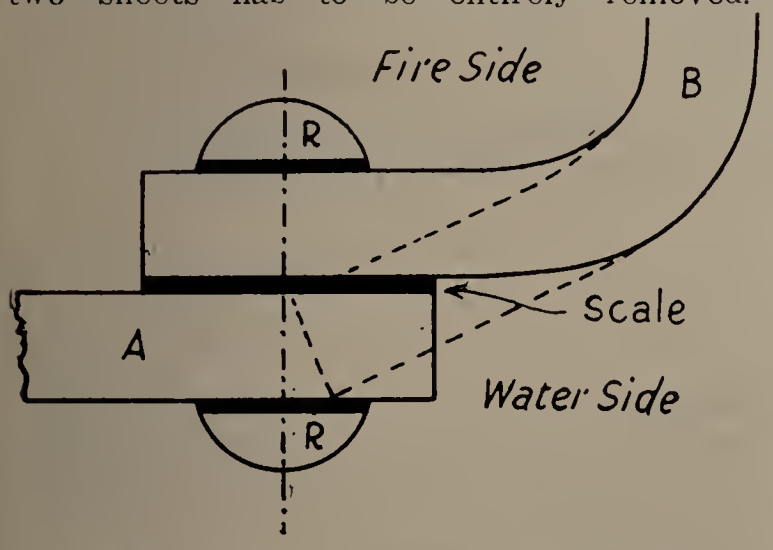
In welding door-holes use the lap or butt weld. In welding a lap weld care must be taken to keep the sheets laid up tight at all times and a fillet weld is applied on the edge. Care must also be exercised to see that the weld is as thick as the sheet in all places.

In welding flues in the fire box end, put the flues in the same as before welding was practiced. The boiler is then filled with warm water so that it will not sweat, and with a roughing tool all dirt and scale is cleaned from the sheet. With an acetylene torch or blow pipe all grease and oil are burned from the flue and sheet. The work is begun at the top of the flue sheet and progresses across so that the smoke will get on the flues that are already welded and not on the ones to be welded. Always start to weld a flue at the bottom, welding up each side to the top. Care must be taken that there is no copper sticking out of the sheet as this will cause blow holes in the weld. In welding upright boilers roll and expand the flue and do not bead or use any copper ferrules. Leave the flue about $\frac{3}{16}$-inch from the sheet and weld the bead on.

Cracks in fire box seams are a common source of trouble. They always occur on the fire side of the seam, as the water apparently does not keep this side of the lap cool. Referring to the diagram, the

Location of Ordinary Crack in Fire Box Seam.

sheets A and B are held together by the rivet R. Scale accumulating between the two sheets has to be entirely removed.



How Scale Forms Between Lap Joints.

the center line of the rivets, then by putting the heat on the angle on sheet B and This can be done by cutting right through hammering outward it soon reaches a position as shown by the dotted line. From there on it is strictly a case of straight welding. There is a gap between the two plates and every 4 in. there is a rivet to be filled up, but this requires only the usual care which is used in boiler welding. The weld is made close to the corner so contraction is all provided for and causes no difficulty. See chapter on "Boiler Welding."

"Fitswell"

Trade name for welding goggles. Made by Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. (See Table of Contents, Catalog Section).

Flame Characteristics

See "Neutral Flame," "Carbonizing Flame" "Oxiding Flame" and "Flame Chart."

Flame Propagation

The speed at which a mixture of gases burns. In a mixture of oxygen and acetylene this might reach a speed of three hundred and thirty feet per second, according to competent authorities. In other words, under certain conditions it is necessary that the mixture of oxygen and acetylene is traveling at a rate greater than three hundred and thirty feet per second in order to avoid burning back of the mixture. Investigations have shown, however. that the mixture of gases producing a neutral cone or flame does nct have this speed of flame propagation, and furthermore, the richer the mixture is in acetylene, the slower the speed of flame propagation. See Back Fire. Flash Back and Pre-ignition.

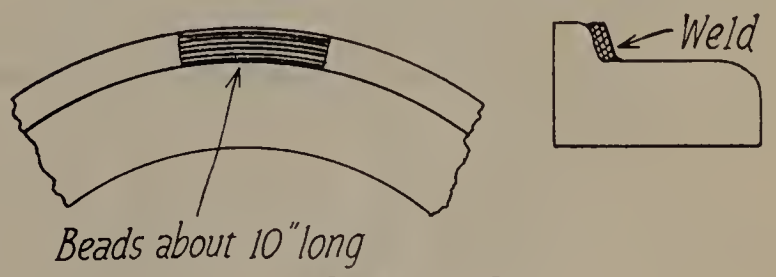
"Flameblast"

Trade name for gas-electric blow torch. Made by North American Mfg. Co., 8918 Frederick Ave., Cleveland, Ohio.

Flanges

Building up worn tires of locomotive wheels has become common practice on several railroads, and it is especially valuable as a salvage process when it is a question of one tire in a set, the others not being worn to the rejection point.

One method of doing this job by the oxy-acetylene process is to remove the tire from the wheel and place it on a trestle or face plate, flange down. Preheating the tire is not absolutely essential but it might tend to facilitate the operation if the heat was applied uniformly around the circumference of the tire. To heat the tire locally in a forge before laying in the welding metal will warp the tire. The usual method is to start one or two welders on the tire without



Flange Weld.

preheating. The welding metal is then laid in until the flange is brought up to contour and takes the gage full. The welder then makes use of a fuller and hand hammer to bring contour down to gage. It is best to use a welding wire higher in carbon than the tire itself. Some welders have experimented to a certain extent with turnings from tires, drawing out and using these turnings instead of welding wire. This procedure has not been satisfactory. After building up the flange, the tire can be turned if necessary. The usual practice is to mount the tire on the wheel and use an abrasive wheel-truing brake shoe in order to bring the tires down to normal contour.

When building up these flanges by the electric arc (metallic electrode) process it is recommended that the beads be laid around the circumference of the wheel, as shown

in the accompanying sketch. By selecting a small electrode, and a correspondingly low adjustment of the amperage, a minimum amount of heat will be used. Instead of laying a bead all the way around the tire, a short section is completed and then a new section started. This procedure allows the metal to be laid smoothly without extra effort, and smoothness is a desirable result in this particular job. At the same time the arc is kept in motion and its heat is localized, so that the heat effects on the structure of the parent metal are minimized.

Flashback

When the flame disappears from the end of the tip and the gases burn within the torch, necessitating shutting off one or both gases to stop combustion within the torch. See Back Fire, Flame Propagation and Preignition.

Flat Position

See "Position of Weld."

Flash Weld

A form of electric butt-welding, generally used on stock that is wide and thin; sometimes advisable when the welding faces are not cut square and true. It is also used in welding tubing to tubing—in fact, in all cases where a small amount of stock is to be taken up in the weld, or when it is desired to shear or grind off the fin. The space between the clamping jaws of the butt welding machine is never more than the diameter of the stock when making a flash-weld, generally it is only 0.7 times the diameter of the work.

See chapter on "Electric Resistance Welding."

"Flexwell"

Trade name for welding compounds. Made by Sani-Products Co., North Chicago, Ill.

Floors, Welded Steel

All welded steel floors provide a durable and sanitary arrangement, and are not difficult to install. Figure 1 shows the details of floor construction used in the milk room of a large candy factory. The plates for this floor are cut 4 ft. by 10 ft. and planed to a 45° bevel, with this bevel running down to a sharp edge. The rigid method of welding was adopted, using the step back system in 6-in. steps, filling the V two-thirds full first layer, then cleaning and applying the second layer in the opposite direction. (See Figure 2). By taking short steps and overlapping the sections of the first layer with those of the second, the stresses were distributed through the weld. The plate used was ⅜-in. thick, and a $\frac{5}{32}$-in. electrode was used, keeping the current as low as possible.

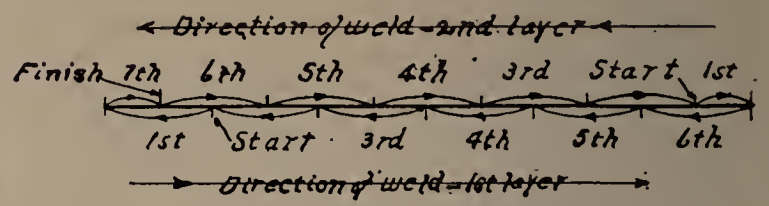


Fig. 2—Filling Sequence.

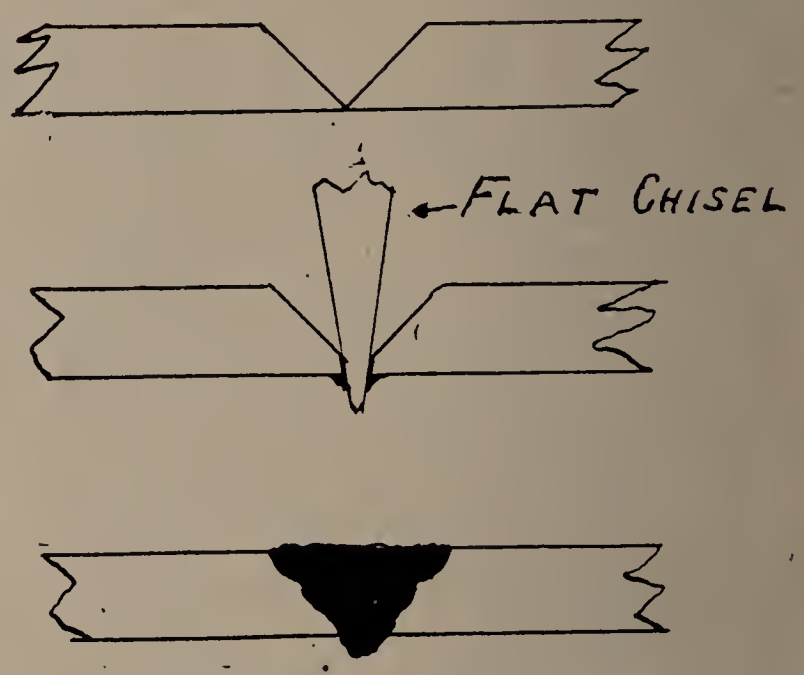


Fig. 3—Method of Reinforcing.

As there is no chance for reinforcing on the top of the floor, the device illustrated in Figure 3 was used to secure the reinforcement on the bottom. The edges were turned down with a pneumatic chipping hammer after the plate was tacked into position. This provided an opening which allowed a slight reinforcement on the bottom. During the welding, trucks loaded with sand bags were placed on plates to hold them down and prevent buckling. Then, after the welding was completed, some spots still had a tendency to bulge, and this was overcome by making a counter-sunk hole in the sum-

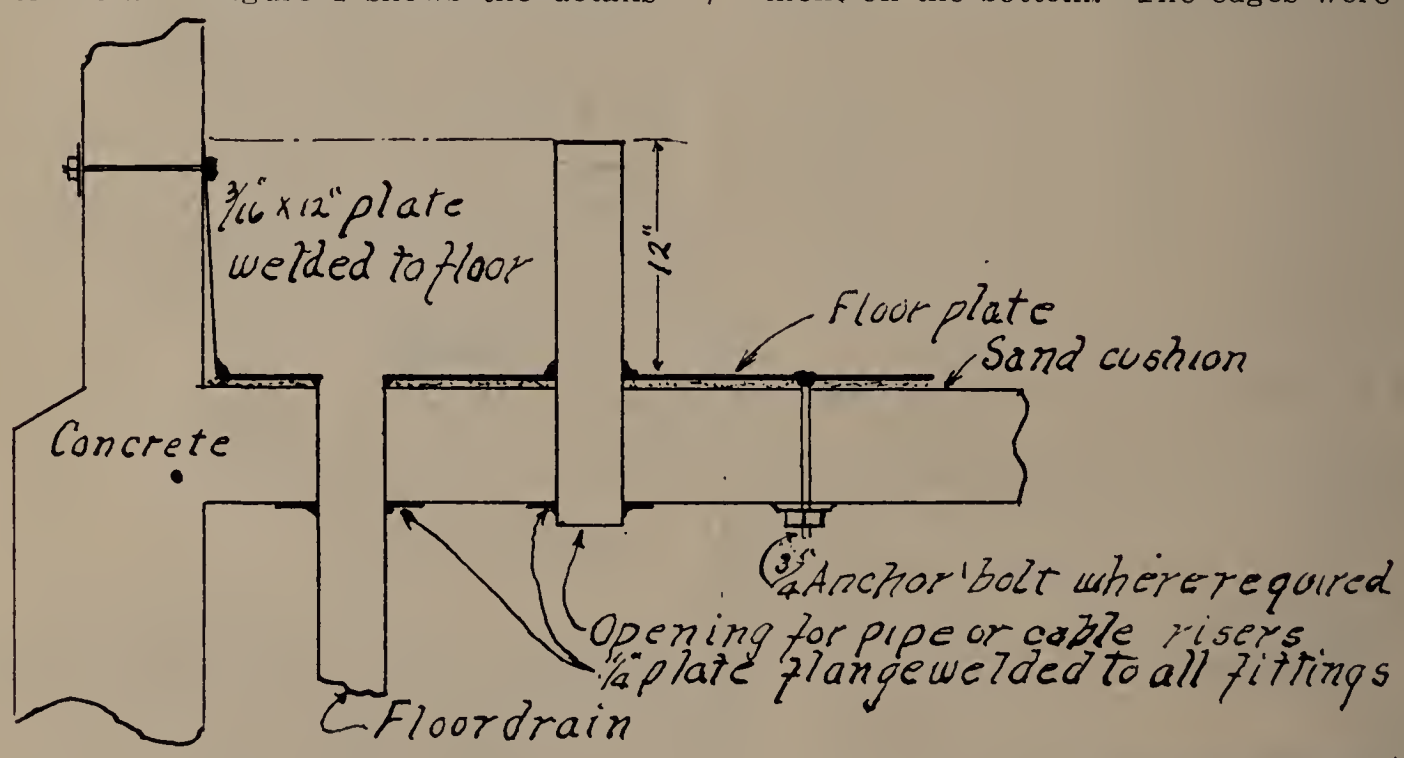


Fig. 1—Floor Construction.

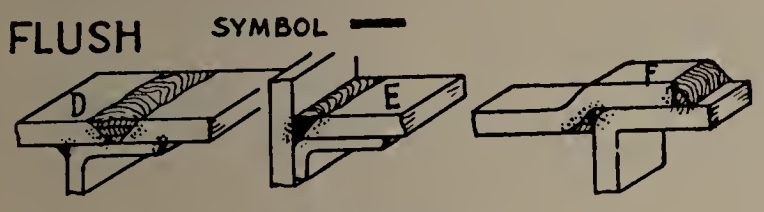
mit of the bulge, and going through the concrete, then placing a counter-sunk through both as shown in Figure 1, and drawing the bulge down to the proper level. All door frames were of steel, with washboard and floor plate welded to them. Figure 1 shows how the pipes were taken through and the drains attached, and the washboard welded to the floor.

Flow Indicator

An individual "meter" or measuring instrument which determines the exact amount of gases being used by each torch. With the aid of this instrument an experienced operator soon finds the most efficient mixture of gases for a certain class of work by noting the position of the indicator on the instrument. Thus the same flame may be obtained at any time. This instrument serves as a useful and accurate check on quantity of gas being used and efficiency of operators.

Flush Weld

FLUSH is a term applied to a weld when the top layer is finished perfectly flat or on the same plane as on the adjoining material



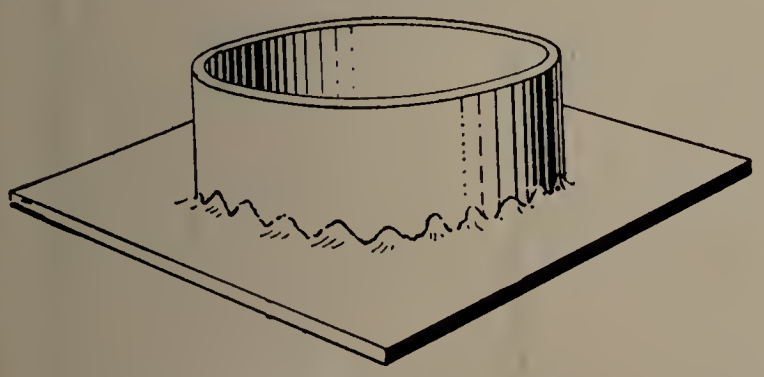
Flush Weld.

as shown at "D" and "E" or at an angle of 45 degrees when used to connect two surfaces at an angle to each other as at "F." This type of weld is to be used where a maximum tensile strength is not all important and must be specified by the designer, together with a minimum number of layers of welding material.

Flux

A cleansing agent used to dissolve oxides, release trapped gases and slag and to cleanse metals for welding, soldering and brazing.

Fluxes usually are packed in powder form in tin cans. Some of them lose their welding properties if exposed too long to the atmosphere, and in such cases small containers are best. Some welders make use of a flux box as illustrated here, consisting of a short section of large pipe, welded to a heavy plate about six inches square. This is a good way to prevent tipping over the flux while a job is under way. It holds only a small amount of flux so if anything hap-



Handy Flux Box.

pens to it, it can easily be refilled from stock and the loss is small.

"Fluxweld"

Trade name for flux-coated low carbon electrodes. Made by Steel Sales Corporation, 129 S. Jefferson St., Chicago, Ill. See Table of Contents, Catalog Section.

Flux-Coated Electrode

An electrode, for metallic electrode arc welding, entirely coated with a flux. The purpose of the flux is to unite with undesirable impurities in the fused metal and float them away as a gas or heavy dust.

"Fluxine"

Trade name for a brazing flux. Made by Krembs & Co., 173 N. Green St., Chicago, Ill.

Forward Weld

Form of pipe welding. The pipe is turned toward the torch and the flame is directed in a semi-circular motion along the plane of the filled-in iron. Its advantage lies in the fact that the iron is subject to preheating in the reducing end of the flame. The fused iron is easily controlled and there is little danger of the fused iron running to a cool spot in the pipe.

Fracture

The crack or break which the welder is required to repair.

Frankolln

Cuprous chloride absorbed in infusorial earth; used as a purifier for acetylene.

Free Distance

The minimum distance between the edges or surfaces of two parts of metal sections welded together.

"Fre-Flo"

Trade name for cast iron welding rods. Made by Atlas Foundry Co., Guardian Bldg., Cleveland, O.

Freezing

Term applied to sticking of metallic electrode to part or parts being welded when arc is struck. In case of most 60 volt welding circuits when the electrode is touched to the plate the current will exceed the normal welding current by 40% to 50%. The arc formed by this excess current instantly fuses a portion of the electrode end and the part against which it is struck. The part however, is usually cold so that the fused metal is solidified or frozen almost instantly and therefore if the end of the electrode is not withdrawn exceedingly quickly it will become attached to the solidified metal.

Frog Points

A procedure commonly used for building up worn frog points, switch points and flanges, with the oxy-acetylene torch, is as follows. Heat the part to a dull red with a kerosene torch or a charcoal fire; start at the hottest point first and weld back, carrying the heat along with the work; work six or eight inches at a time, hammering and dressing the weld to a finish; heat the finished surface to a dull red, readjust the torch to a carbonizing flame about an inch long and play slowly across the finished surface four or five times, not allowing the flame to come too close to the metal and being sure to cover all parts evenly (only a couple passes should be given to thin sections, as they may absorb carbon rapidly and become too brittle); weld another six or eight inches and finish the same way. The process is said to give a hard, durable surface, with the strength of good steel.

"Fuellte"

Trade name for gas for welding and cutting. Made by Rockgas Products Co., Pittsburgh, Pa.

Fuller Tool

A round nose chisel sometimes used by welders in welding boilers. The bottom of the V is brought to a red heat and the Fuller tool is driven into the bottom of the V, unsetting same about ⅛ of an inch. The weld is then started and completed in the usual way. It is claimed that the additional filler material provided by the upsetting process helps to compensate for expansion and contraction strains and also provides for thorough penetration at the bottom of the V.

Fuse

To melt metal and cause fusion, or amalgamation of sections to be welded. "Tacks" or "Spots" might be said to be "fused."

"Fuse-Well"

Trade name for cast iron welding rods. Made by Sani-Products Co., North Chicago, Ill.

Fusing
Fusing and freezing points are terms applied to the temperature at which solids assume the liquid form and liquids become solid. Lead, for instance, reaches the fusing point at 620°F, copper at 1996°F, cast iron at 2786°F and iron at 2912°F. See Adhesion.

Fusion Weld
A weld formed by heating to a fluid state the edges of the pieces to be joined and allowing the metals to flow together without any pressure being applied.

"Fyberweld"
Trade name for goggles. Made by Chicago Eye Shield Co., Chicago, Ill. See Table of Contents, Catalog Section.

—G—

"G-E"
Trade name for direct current arc welding machines. Made by General Electric Co., Schenectady, N. Y. See Table of Contents, "Catalog Section."

Gallalith
The German name for "Casenite." See "Casenite."

Galvanized Iron
Galvanized iron cannot be successfully welded. The action of the flame burns the zinc and leaves an unprotected surface at the welding line. The melted zinc is incorporated into the weld and decreases its efficiency. Galvanized sheets should be brazed. The zinc coating of the metal unites with the brazing metal, which should be a composition of copper and zinc. The brazing metal melts readily at the joining edges and spreads on each side about ¼ inch. At the point where the brass ceases spreading the zinc continues to spread, serving as a protective agent. Therefore the brazing process leaves no part of the surface unprotected. When brazing galvanized sheets use a smaller tip than for welding other metal of the same thickness. For a brazing compound use ordinary ⅛-in. brazing wire. For angle iron or heavier sections use $\frac{3}{16}$-inch or ¼-inch Tobin bronze rods. To braze two plates of galvanized iron overlap the edges about ⅛ inch. Tack the edges about every three inches. Then braze from end to end. If expansion distorts sheets compensate for same by hammering. A good brazing job is assured when the brazing metal appears on the opposite side of the brazing line.

"Garnet"
Trade name for fabric covered hose for welding and cutting. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Gas Carbox"
Trade name for coated high carbon rod for acetylene welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Gasol"
Trade name for a gas for welding and cutting. Made by Rockgas Products Co., Pittsburgh, Pa

Gasoline Tanks
Gasoline tanks are made of galvanized iron. The repair is a soldering job. If the tank, however, is not galvanized, leaks can be repaired by the ordinary methods prescribed for sheet metal welding. Precautions should always be taken to thoroughly drain the tank of gasoline, wash it out several times and flush it with live steam. The welding flame should never be brought close to a gasoline tank before steam has been used to clean out the vapors. Half an hour is usually long enough.

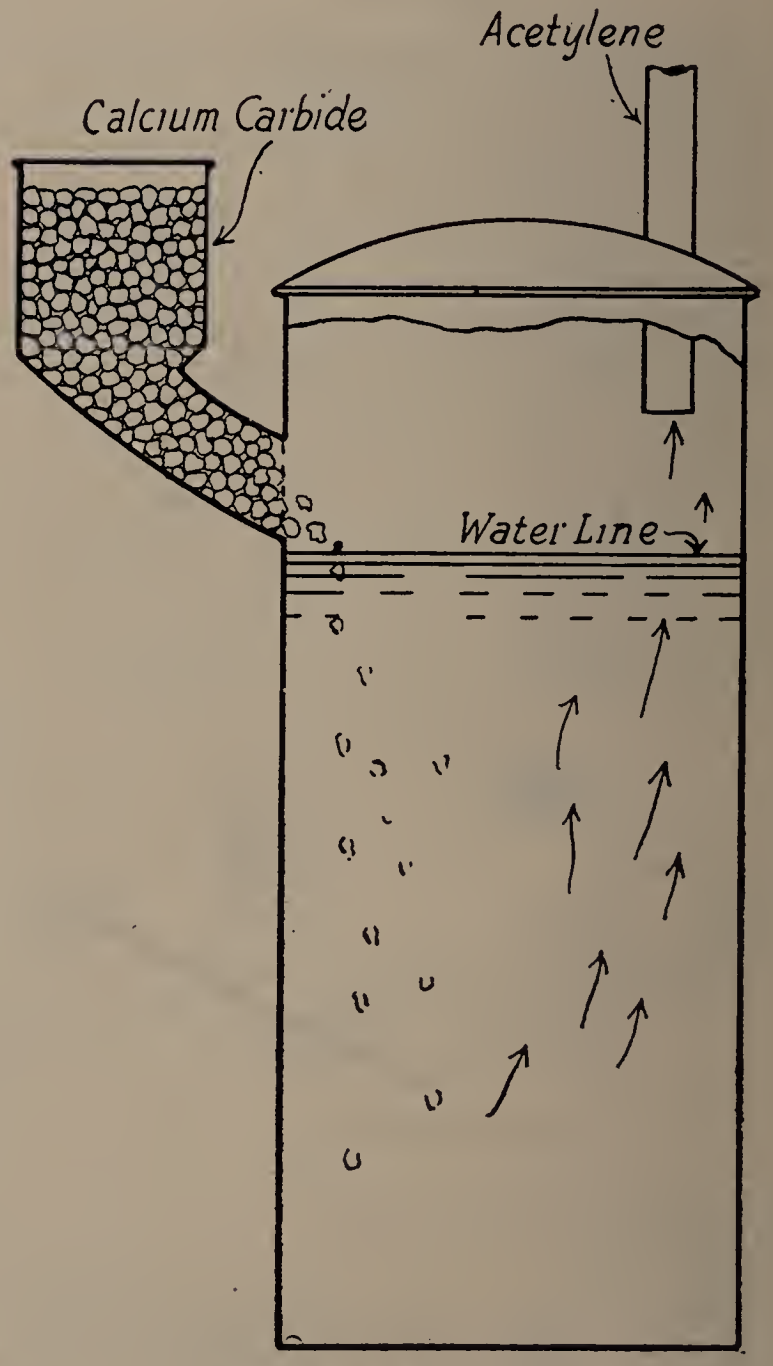
Gasometer
A bell or receiver for storing gases. See Bell.

Gauge
See Bourdon Tube.

Gear Teeth
Broken gear teeth are usually replaced by building up a new tooth on the wheel. The important precaution to be taken in this operation is to supply enough heat to the portion of the weld where the metal is being added so that the metal is always in fusion when the welding rod is being melted into it. It is well to keep it in the fire while the welding is being done. This will insure having a new tooth which can be readily machined or filed to shape.

"Geer"
Trade name for acetylene generators and preheating torches. Made by Straub Mfg. Co., Oakland, Calif.

"Gefei"
Trade name for electric resistance seam welding machinery. Sold by Gibb Instrument Co., Bay City, Mich. See Table of Contents, Catalog Section."



Carbide to Water Principle.

"Gem"
Trade name for bronze welding rods and wire. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air

Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

Generators (Acetylene)

Acetylene is produced by the interaction of carbide and water. The function of an acetylene generator is therefore to bring these two materials into contact in such a way as to produce a cool, clean, pure gas. If this is accomplished the probabilities are that the machine is safe.

There are three general types of acetylene generators which may be classed under the heads of water to carbide type, the carbide to water type and the recession type. The water to carbide and the recession types are used in apparatus designed to produce acetylene in comparatively small quantities; viz.—miners' lamps, bicycle and automobile lamps, experimental laboratory apparatus, etc. The carbide to water type is used where large quantities of gas are employed,—such as city lighting plants, oxy-acetylene installations, acetylene used for charging drums, etc. The patent office records show these systems of generating acetylene modified and combined in endless ways. We are concerned mainly with the carbide to water type, however, as this is the standard equipment for oxy-acetylene welding installations. We will, however, discuss the other two types briefly.

To realize the heat delivered when water and carbide are brought into contact, place a small lump of carbide in the palm of the hand and wet it. If a quantity of carbide is placed in a wire basket, submerged in water and removed after a short interval, the temperature attained within the carbide may on occasions rise to a red heat, under which conditions pure acetylene would not be obtained. In place of acetylene we would find benzine sulphuretted hydrogen, methane, etc., all of which gases would be detrimental to a weld.

The water to carbide generator is one in which the water is usually allowed to drip on a quantity of carbide held in a wire basket, and is satisfactory for small production and might possibly be successful on a large scale if the basket were continually shaken to remove the coating of slaked lime formed on each lump of carbide, as it is this lime that absorbs the excess water and later gradually releases it to the fresh carbide. Slaked lime coats each lump of carbide exposed to the water when water is not used in excess, and being a very poor conductor of heat, effectually retains the greater part of the heat within the basket of carbide. The high temperature, then, is the principal objection to generators of this type. The impure gas alone would condemn it, to say nothing of the danger.

The Recession type of machine is of the same order as it has its basket or baskets of carbide mounted to a gas bell which raises and lowers the carbide to and from the water or else means of raising and lowering the water level are used while the basket is held stationary. This form of generator has the same disadvantages as the water to carbide type and the same element of danger.

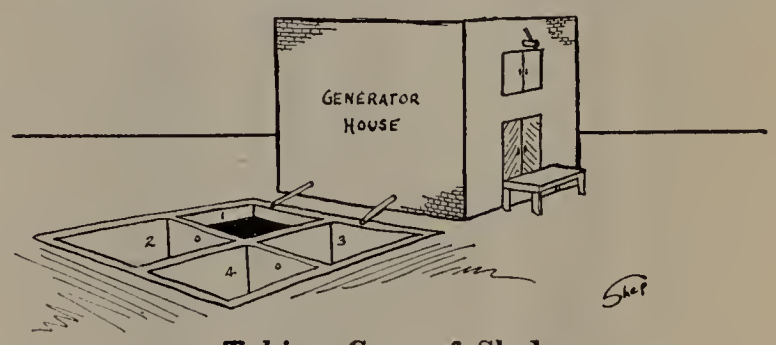
One other important objection to either of these machines is the waste of gas by after generation. By after generation is meant the gas produced after the basket of carbide is removed from contact with the water. The trouble is caused by the spent carbide which absorbs water when in contact with the water and later feeding it gradually to the fresh carbide. Acetylene will be generated until all the moisture is drawn from the lime and as it is difficult to make proper allowances for the amount of gas thus formed, a loss is sure to obtain by means of a relief valve.

The carbide to water type, as the name implies, is one in which carbide is dropped into an excess of water, the standard rules requiring one gallon of water for each pound of carbide. Each lump as it enters the water is quickly converted to gas and lime. The lime is washed off by the agitation of the water due to the rapid ebullition of the gas and the heat is readily absorbed by the water. The result is clean, cool gas, free from lime dust and other impurities. Lime water is in itself a good purifier for acetylene, and this is what is formed when carbide is dropped into water.

Some of the objections to the water to carbide and recession type generators might be present under certain circumstances even in the carbide to water type machine. In event a too finely crushed carbide is used it is apt to lie on top of the water, supported by the minute gas bubbles adhering to the dust particles and thus prevent carbide following it to reach water in sufficient quantity to prevent it from heating. Large carbide is therefore to be preferred. Nothing smaller than ¼x1/12 in., and preferably 1¼x⅜ in. is recommended.

Trouble might arise under another condition and that is when several charges of carbide are fed into the machine without changing the water. The lime water or sludge, as it is called, then becomes so thick that when a lump drops into it there is not sufficient water to wash the slaked lime from it, but just sufficient to gradually seep to it through the thick sludge. On occasions carbide is known to have attained incandescence under these conditions.

So much for the methods of generating acetylene. We now come to the choice of the machine. In this connection the writer pauses to recommend any particular modification of the carbide to water type of machine, but will not hesitate to say that any generator made by a responsible manufacturer may be considered safe. It will not be out of place though to say that the simplest machine is not necessarily the safest; nor that the most elaborate may not prove dangerous. Too many and too complicated pieces of mechanism are apt to prove troublesome in generators as they do in other machines. Simplicity is to be commended, but not to the point where it might eliminate the use of certain necessary safety



Taking Care of Sludge.

contrivances.

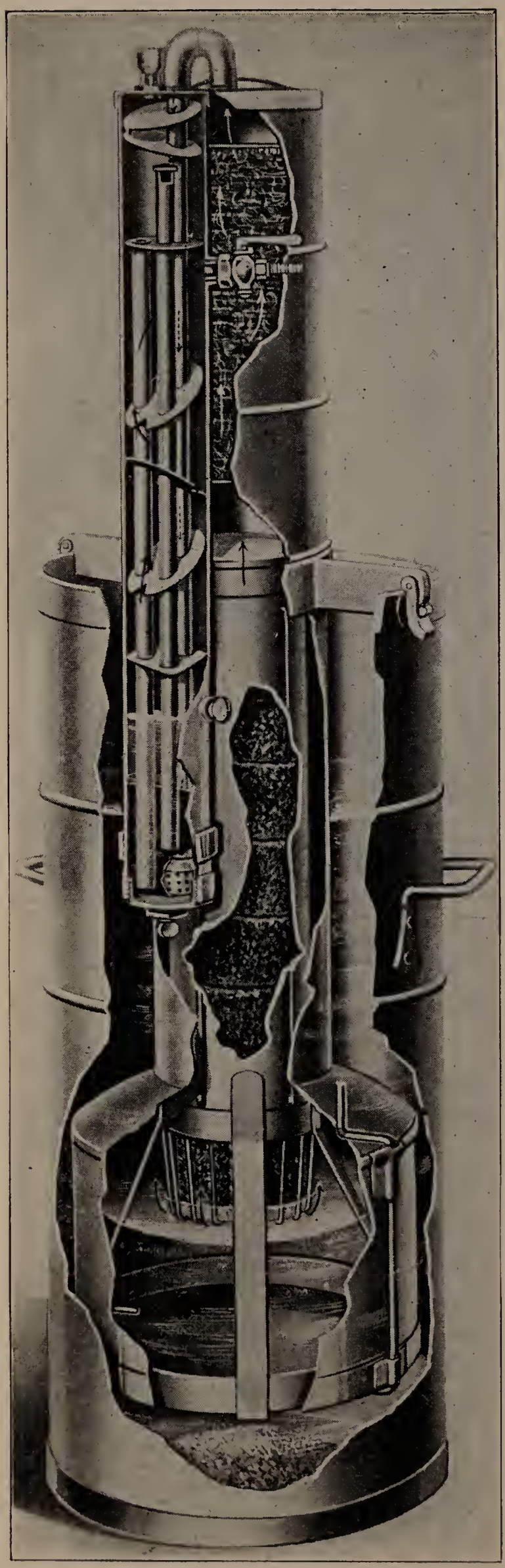
The subject of safety is the first factor to be considered in an acetylene generator, and American manufacturers are today manufacturing acetylene generators which are both safe and efficient.

Insurance underwriters require acetylene generators to operate with a comparatively low pressure, not to exceed 20 pounds per square inch and in general somewhat less than 15 pounds. (See Underwriter's Laboratories Specifications.)

When a large capacity generator, or battery of generators, is used to supply the acetylene some attention needs to be given to the arrangement and installation of the outfit. The rules for installation and operation, as given in the section on "Rules and Regulations" must of course be observed. It is also well to construct a large and stout storage platform for carbide above the level of the filling opening, so the man in charge of it will have something solid to stand on while recharging.

To take care of the residue, or sludge, it is a good idea to construct a large concrete vat near the generator, about six feet deep and twelve feet square, and divided into four compartments. The used

water and sludge are discharged into one compartment and the sludge settles to the bottom. When one compartment fills up the water will flow into the next and gradually disappear due to evaporation and leakage, leaving slacked lime, which can be dug out and used for various purposes.



Carbic Generator.

The Carbic type of portable low pressure acetylene generator employs the use of specially prepared calcium carbide in briquette form. Notice in the illustration the position of the cakes in the cake holder, also the location of the cake holder in the gas bell. As the gas bell (with the cake holder inside and outlet valve closed) is lowered into the water tank, during the charging operation, the water seeking its own level, comes up a few inches into the bell until the air pressure in the upper part of the bell prevents it from rising higher. Then when the outlet valve is opened, the water begins to rise slowly in the gas bell until it touches the bottom of the lower cake. From this contact gas is produced and the gas thus generated again forms a pressure in the bell which forces the water down away from the cake and the generation ceases. The bottom of the cake automatically frees itself from sludge and dries, remaining in that condition until the water again rises to touch it and from additional gas. The pressure of the gas, therefore, is at all times automatically maintained by the alternating pressure of the gas in the gas bell and the water column in the tank.

The sludge or residue, freed from the cake, drops to the bottom of the tank and as it accumulates there, raises the water level in the tank just enough to displace the loss in the height of the water column, due to the consumption of the water which takes place in the generation of gas. The generator may be used intermittently as required by merely opening and closing the outlet valve. No additional water is required for the complete consumption of the charge and the entire operation continues automatically. It has a single charging capacity sufficient to produce eighty to ninety cubic feet of acetylene.

Low pressure acetylene generators produce acetylene at a pressure of less than one pound, the gas being stored in a gasometer When the gas reaches a predetermined height the generator stops feeding carbide. This type generator necessitates the use of a torch of the injector type.

Medium pressure acetylene generators operate on a pressure not to exceed fifteen pounds.

For detailed specifications and rules of Underwriters' Laboratories see section relating to laws and insurance regulations.

The instructions of manufacturers relating to the care and operation of acetylene generators should be carefully studied and read. See "Acetylene."

Generator (Oxygen-Hydrogen)

See Oxygen.

"Gewe"

Trade name for automatic oxy-acetylene welding and cutting machines. Made by General Welding and Equipment Co., 74 Brookline Ave., Boston, Mass. See Table of Contents, Catalog Section.

"Globe"

Trade name for welding vise. Made by Albert Lea Foundry Co., Albert Lea, Minn.

Goggles

Scientifically colored glasses for welders. Both oxy-acetylene and electric welders should protect their eyes, either with goggles, shields, helmets, or some form of eye protection. See "Eye Protection."

Grain

A term used for an allotrimorphic crystal present in metals and in one-constituent alloys. Although a crystal may show division by "twinning," etc., it is regarded as the grain rather than smaller sub-divisions. In the case of alloys of more than one constituent, the crystal which, by its transformation, gave rise to these constituents is taken as the grain when its limits are still

discernible; if the limits are not discernible the individual constituents are considered as grains.

Grain Size

This is preferably expressed as the number of grains per unit area of cross-section. The average cross-esctional area of the grain may also be given or the average dimensions. Grain size of strained material is expressed by the average number per linear unit in two directions, or by the average number per unit cross-sectional area, together with the ratio of length to breadth (L/B.)

By the "intercept" Method for grain count, the number of grains and fractions of grains along a line of known length on two axes at right angles to each other are counted. By the "Planimetric" Method for grain count, the number of grains and fractions of grains within a definite area are counted.

Graphite Arc Welding

The application, for welding, of the heat from the electric arc between a graphite rod and the work or between two graphite rods to melt a third metal. See "Carbon Electrode Welding" in chapter on Electric Arc Welding.

Graphite Electrode

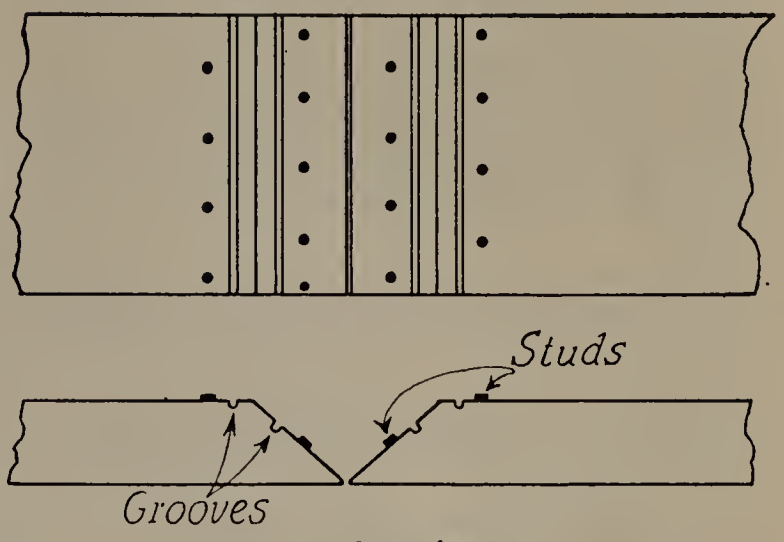
An electrode comprising the same base and binder used for hard amorphous carbon but having been baked at a sufficiently high temperature for the proper length of time to graphitize the binder.

"Green Drum"

The distinguishing mark of drums containing carbide. Made by Shawinigan Products Co., 160 Fifth Ave., New York, N. Y.

Grooving

When welding cast iron with the electric arc process studs are inserted in the casting, as explained under "Studding" in the chapter on "Electric Arc Welding." A further



Grooving.

aid to assist in securing a good weld is found in chipping out an irregular narrow groove between the rows of studs, as shown in the sketch. See also "Arc Welding Cast Iron" in chapter on "Electric Arc Welding."

—H—

"H"
Trade name for an aluminum flux. Made by Bierman-Everett Foundry Co., Irvington, N. J.

"Hackney"
Trade name for cylinders. Made by Pressed Steel Tank Co., Milwaukee, Wis.

Hand Shield
A device similar to the hood, being lighter, smaller and provided with a handle by which it is held before the operative's eyes, thereby allowing only one hand free to handle electrode holder. See "Eye Protection."

"Harris"
Trade name for oxy-acetylene welding and cutting equipment. Made by Harris Calorific Co., Cleveland, Ohio. See Table of Contents, Catalog Section.

Hardness
Property of metals rendering them resistant to the action of cutting tools.

Hard Soldering
Same as Brazing. See "Brazing."

Hard Spots In Cast Iron
See "Cast Iron."

"Hardy"
Trade name for welders' goggles. Made by F. A. Hardy & Co., 10 S. Wabash Ave., Chicago, Ill.

Harmatta Process
An electric spot welding process, patented Dec. 3rd, 1912. Practically the same as the De Bernado, except that copper electrodes are used.

"Hauck"
Trade name for oil burning preheating, brazing and other equipment used in welding shops. Made by Hauck Mfg. Co., 130 10th St., Brooklyn, N. Y.

Heat Conductivity
The property of allowing the passage of heat. Silver possesses the property of rapidly conducting heat and the heat conductivity of other metals is generally given as compared to that of silver.

Metals possessing high heat conductivity require a larger flame because the heat is conducted rapidly away from the puddle.

Heat of Fusion
Amount of heat necessary to melt one gramme of a substance without change of temperature.

Heratol
Chromic acid absorbed in infusorial earth: used as a purifier for acetylene.

"Heylandt"
Trade name for air liquefaction oxygen plants. Sold by H. G. Amling, 139 S. 20th Ave., Maywood, Ill.

High Line Gas
See "Butane."

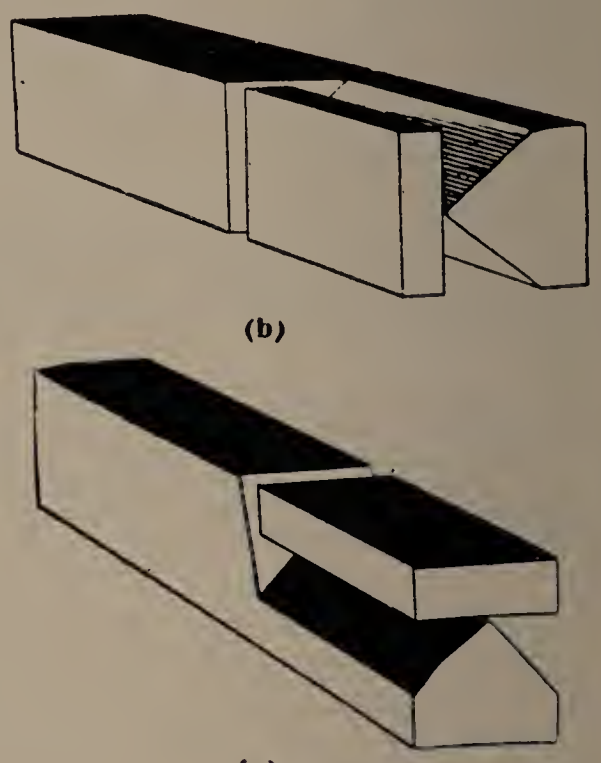
"Hicarweld"
Trade name for high carbon steel rod for track welding. Made by Steel Sales Corporation, Adams and Jefferson Sts., Chicago, Ill. See Table of Contents, Catalog Section.

High Pressure Principle
See "Torch Classification."

High Speed Steel
The autogenous welding of tips of high speed steel to low carbon shanks is perfectly feasible and several processes of performing this work are in successful use. As a means of lowering costs of production the process commends itself to manufacturers, engineers and plant managers.

The principal reason for the failures of the welder who attempts this class of work is because of his ignorance of the class of steel he is attempting to weld and because of a lack of practice. Therefore, it is plain that to acquire skill in the welding of high speed tips to low carbon steel the operator must not be discouraged by a few failures, but must master the problem by study and practice.

So far as the low carbon steel used as shanks is concerned, this steel may be roughly divided into three general classes: Cold drawn, open hearth and Bessemer. The high carbon steels are more numerous and many metals enter into their composition. No doubt the bulk of the welder's failures would be eliminated if he had a perfect understanding of the varied and intricate



(b)

(a)

Fig. 1.

analysis of many of the high carbon steels of the day. He often fails to appreciate that, controlling a heat of 6,300° Fahr. he plays it unnecessarily long on a steel which melts at from 1,800° to 2,500° Fahr., which results in burning the metal. In the mills where such steel is made, should a furnace be allowed to reach such a temperature, an entire heat would be destroyed.

The first step in weiding high speed tips to low carbon shanks is the preparation of the shank, which is beveled as shown in Fig. 1. The tip of high speed steel is not to be beveled. The shank and tip should then be sand blasted, after which the sand dust should be wiped off the surfaces to be welded. In order to avoid the interior oxidization of high carbon steels it is good practice to preheat both the shank and the tip to a cherry red (about 1,375° Fahr.). Then build up ⅛ inch of metal on the surface of the shank that is to be welded, and also on the surface of the tip which is to be welded, using a $\frac{3}{16}$ or ¼ inch nickel steel welding rod and a flux such as is used for cast iron. Then place the tip in the position it is to occupy, as shown in Fig. 1 (a) and tack it and weld that side with a nickel steel rod. A flux is not necessary. Turn the tool over and weld the other side. Both sides should be welded from the end, progressing toward the heavy portion of the shank.

The reason for this is as follows: The low carbon steel (the shank) will absorb heat more rapidly than high carbon steel (the tip). As the flame is progressing towards the shank the high carbon tip is therefore subjected to as little heat as possible, and the shank will absorb the most of it.

Now set the tool up on edge, as in Fig. 1 (b) and weld the sides and top, where the high speed steel joins the low carbon shank. In order to reduce as much as possible the interval between the beginning and the ending of the welding operations a sufficiently

large tip should be used and care should be taken that the flame is not played on one spot too long, or the metal will be burned.

It will be noted that a nickel steel welding rod is recommended, although in justice to some very capable welders it may be said that in certain shops both Norway or Swedish iron rods and Vanadium steel is being used. The author believes, however, that the results attained justify the statement that nickel steel rods are preferable.

Many welders overlook the fact that the physical properties of high speed steel and ordinary tool steel are so different that strains are set up by welding. Therefore, it is essential that the welded tools be heat treated before cooling from the welding operation. When possible a furnace should be used for this purpose. If the life of the tool is of but short duration, it is sufficient to bury it in lime or asbestos as soon as the welding operation is completed. Another good method is to place the tool on end and in a tank which contains any good mineral oil. This tempering or hardening process should take place after the welding operation and before the tool cools.

As was pointed out at the beginning, in the welding of high speed tips to low carbon shanks, much depends on the operator. In ordinary tool room work when a difficult or intricate tool or jig has to be made, the foreman selects one of his best men to do the work. In the case of failure, the human element is blamed. With the oxy-acetylene process, however, the blame is too frequently placed on the process or the apparatus. Too often the verdict is, "No good for that kind of work." This snap judgment is usually due to a lack of knowledge on the part of both the welders and their foremen. In handling work of such a special character as welding tools it should be understood that the welder should, if he is not already experienced in that work, be given an opportunity to study and practice and his first failures should neither condemn him or the process. The results to be derived from patience will justify the expense of the welder's training.

One of the largest makers of tools in America, welds high speed tips to low carbon shanks in the following manner: The shanks are first formed and then that portion of the surface of the shanks which is to be welded is sand blasted, as is also the high speed tip. (The welding surface is then cleaned.) A piece of ordinary Swedish or Norway welding rod, which has been properly flattened and sand blasted, is then placed on the shank between the shank and the high speed tip. The tool is then placed in the furnace, which operates from city gas, and the tool is brought gradually to a temperature of about 2,250 to 2,275° Fahr., or in other words, to a white heat. (Time consumed, about three hours.) The tool is then removed from the furnace and placed in a small press, which is screwed down to give the necessary compression. If a press is not available, the tool may be welded by simply striking the high speed steel a sharp blow with a hammer. The tool should not, however, be subjected to continuous tapping, as this has a tendency to destroy the adhesion secured by the first blow. The tool should then be immediately plunged in an oil bath. In this connection, any good clean mineral oil is perfectly satisfactory and it is not necessary to use either fish oil or linseed oil. The tool is then ready for grinding or dressing.

For methods of butt welding and spot welding of high speed tips to low carbon shanks, see chapter on "Electric Resistance Welding."

"Hisey"

Trade name for electric grinding machines. Made by Hisey-Wolf Machine Co., Cincinnati, Ohio.

Histed

Trade name for goggles made by J. E. Histed, 110 E. Franklin St., Richmond, Va.

Holograph

Trade name for a mechanical cutting torch. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

Hood

A device mounted on the operative's head or shoulders for protecting the head and provided with proper glass for protecting the eyes of the operative from the injurious light rays emitted by the arc. This device allows operator to use both hands for handling electrode holder, etc. See "Eye Protection."

Hopper

The receiver for calcium carbide in an acetylene generator.

Horizontal Welding

Level or parallel welding. Applied to welding in a level position. See "Position of Weld."

Horn

Electrode holder of an electric resistance spot welding machine.

"Hos"

Trade name for aluminum welding flux. Made by Hoskins Process Development Co., 4035 W. Kinzie St., Chicago, Ill.

Hose, Welding

Welding hose, used for connecting the torch with the gas supply, should be strongly built to resist the pressure of the gases and stand up under the constant bending and twisting incident to the work. A good grade of hose should be used because a cheap or inferior hose may disintegrate inside, which means a clogging of the needle valves and the introduction of impurities into the fused metal. Metal covered hose is not generally recommended because the presence of leaks is not easily detected or remedied, and it is too heavy for the operator to handle comfortably.

Two colors of hose are used for gas welding; black for acetylene and red for oxygen. This is to prevent confusion when connecting apparatus. See that hose connections are tight. Use a good hose clamp. Both acetylene and oxygen hose should be blown out occasionally so that dirt and dust will not be carried into the torch.

Hot Short

Condition of metal when it proves to be very brittle at red heat although it can be bent without showing signs of brittleness when cold or at white heat. This condition is largely due to a high sulphur and phosphorus content.

Housings, Malleable

Malleable rear housings are usually brazed. Either tobin bronze or manganese bronze can be used. Use a torch with a large tip so that it will not be necessary to bring the flame close to the metal to melt it. Avoid an oxidizing flame to the extent of having the same slightly carbonizing in order to be on the safe side. Do not allow the cone of the flame to touch either the bronze rod or the casting. If necessary to secure additional strength, wrought iron straps can be brazed transversely to the break. If a good tight weld is desired, it is advisable to preheat the casting before starting to braze. See the instructions for brazing and also the discussion of malleable iron.

Housings, Tubular

When the drive shaft housing of an automobile has broken close to the malleable casting into which it is fitted. A new tube several inches long should be riveted or brazed into the casting and the old housing shortened so that it will be the proper

length when welded to the new tube. It is not advisable to make a weld close to the casting where the break usually occurs.

Hyde Welding Process*

Some few years ago a method of uniting iron and steel which partakes of the nature of both welding and brazing was invented by Mr. A. C. Hyde, of the Hyde Welding Co., Wolverhampton, England. This method, which is now in commercial use, consists essentially of uniting the surfaces by means of molten copper, but it differs from brazing in the fact that the copper impregnates the mass of metal to be joined and unites them in such a way that they cannot again be separated by heat.

The process is usually carried out by placing together the pieces to be joined with a small piece of copper wire or strip adjacent to but not between the joint, and then raising the whole to the melting-point of copper while surrounded by an atmosphere of hydrogen. With articles of ordinary size they are simply put into a muffle furnace through which hydrogen is passed, the gas being ignited and burnt as a small flame where it leaves the furnace. The surfaces need not be cleaned nor is any kind of flux used. The effect of the hydrogen is to reduce any rust or scale to the form of spongy metallic iron, which presents an excellent surface for the copper to penetrate. If a small piece of copper is placed on an iron plate and heated in an atmosphere of hydrogen to the melting point of the copper it spreads out at once over the iron in a film.

The fluidity of the copper melted under such conditions is extremely high and penetrates the minutest crevices. This somewhat remarkable result cannot be due entirely to the deoxidizing effect of the hydrogen because equal results are not obtained when the atmosphere consists of other deoxidizing gases. The hydrogen appears to act as a flux, cleansing the surfaces and causing the copper to wet it and to flow freely over it.

In connection with the process an important phenomenon is observed. The copper not only "solders" the surfaces together in an effective manner as shown by microphotographs, but if the joint is maintained at a high temperature for any length of time after the copper has melted, the latter metal permeates the steel faces for a considerable depth, forming an alloy of steel and copper with individual characteristics.

It is not necessary to use pure copper to obtain the effect described as alloys of copper and tin give the same result. Another remarkable property obtained with the process is that welded articles exposed to damp and corrosive fumes which do not attack copper readily, apparently go rusty in time although far less rapidly than the usual electro-coppered ones. If the apparently rusty surface is rubbed and polished, the copper surface will come out again bright and new, it has neither peeled off or otherwise disappeared.

The practical utility of the process has been demonstrated in many ways; for example, in the manufacture of the cage or body of high-speed centrifugal governors for small steam turbines, and for the attachment of distance pieces to the roots of turbeing the cowl or cover into which the application to the cardan shaft of the Lanchester motor car. The hollow tube forming the body of the shaft is joined to the splined ends and the joint made by the Hyde process.

The forms of apparatus for effecting the process economically are varied, and depend largely upon the articles to be treated. It is claimed that the quickest and most practicable way of bringing the joint to the required temperature is by the resistance method.

The parts to be welded are quickly gripped in the jaws of a standard butt welding machine[1], the capacity of which varies according to the sizes of the metal dealt with, the only additional fitting required being the cowl or cover into which the hydrogen is sprayed; this cowl is provided with a mica inspection window so that the current can be switched off immediately sufficient temperature to melt the copper has been reached. The object of the cowl is to ensure the least possible waste of hydrogen.

Several applications of this system in conjunction with standard 6 K. W. butt welding machines have been carried out of which a few are as follows:

(1) The welding of steel flanges on to steel tubes.

(2) The welding of 0.6 carbon steel to mild steel bar.

(3) The welding of the covers of steel windows.

This is the only process whereby a thoroughly strong joint can be made without any cleaning off whatever being required. The total cost including power, copper, and time costing approximately 1 cent per cover.

In each case the gas chamber is provided with an inspection hole covered with mica so that immediately the operator sees the copper run he can turn off the current and take out the work. It is an advantage to leave the current on for a short time as this tends to allow the copper to penetrate the surface to a greater depth, but for ordinary work this is not required.

The jigs employed are inexpensive and simple and easily adaptable to standard machines.

Hydrated Lime

Placed about a casting after welding to prevent any air getting access to the weld.

"Hydrex"

Trade name for a gas "meter" or indicator or recording apparatus. See "Flow Indicator." Made by Hydrex Engineering Corp., Buffalo, N. Y.

Hydrogen

Hydrogen is a chemical element that occurs in free state in the gases of certain volcanos. In combination with other elements it is found in most organic bodies and many inorganic bodies. Water is a chemical compound of hydrogen and oxygen, in which approximately 11% by weight is hydrogen.

The chemical symbol for hydrogen is H. It is the lightest element known, and has an atomic weight of 1.008, as compared with 16 for oxygen. The density as compared with air is .0695. In gas form hydrogen is a colorless, odorless, and tasteless gas. When liquified it is a clear colorless liquid. Under atmospheric pressure the boiling point of hydrogen has been found to be —422.5° F. The critical temperature is —401.7° F., and its critical pressure 15 atmospheres (220 pounds per square inch.)

Hydrogen combines readily with oxygen in the presence of heat, and forms water. Hydrogen and oxygen burn together with an almost colorless flame, and produces a very hot flame that can be utilized for various purposes, such as lead burning, light welding, and as a preheating flame for cutting. The principal objections to the oxyhydric flame is that it is very difficult to determine whether the flame is neutral or not, on account of the absence of a definite inner cone in the flame. Attempts to overcome this difficulty have been made, by mixing the hydrogen with some other combustible gas that will produce an easily seen inner or luminous cone when burned with oxygen.

**Written for The Welding Engineer by D. Richardson.*

[1]*See chapter on "Electric Resistance Welding."*

Hydrogen can be produced chemically from various compounds, but for all practical purposes hydrogen is now produced by means of electrolytic dissociation of water. (See Oxygen.,

Hydrogen is supplied to the trade in seamless drawn steel cylinders, charged to a pressure of 1800 pounds per square inch, at 70° F. The size of hydrogen cylinders standardized by the general trade have a capacity of about two hundred cubic feet at the above mentioned pressure. The cylinders must comply with shipping Container Specification No. 3A, issued by the Interstate Commerce Commission and all transportation of these cylinders must be in accordance with the regulations adopted by said Commission, and now in force. The Bureau of Explosives, No. 30 Vesey Street, New York City, should be consulted for proper labeling and instructions.

Hydrogen, Electrolytic Production
See "Oxygen, Electrolytic Production."

Hydrostatic Test
See Section 372, Report of Boiler Code Committee, A. S. M. E., in chapter on "Rules and Regulations."

"Hygrade"
Trade name for soft steel welding rods. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Hytempite"
Trade name for a high refractory plastic material. Made by Quigley Furnace Specialties Co., 26 Cortlandt St., New York City.

—I—

I-Beam
Castings may often be lined up well on an I-Beam, which serves the purpose of a straight edge. For welding of I-Beams see "Structural Steel."

"Ideal"
Trade name for goggles. Made by Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. See Table of Contents, "Catalog Section."

"Ideal"
Trade name for a shield for electric arc welders. Made by Ideal Face Shield Co., 468 N. Garfield Ave., Columbus, Ohio. See Table of Contents, "Catalog Section."

Impact Bending Test
A test for resilience, the blow being applied in a direction parallel to the joint.

"Imperial"
Trade name for welding and cutting torches, accessories, supplies, regulators, acetylene generators, etc. Made by Imperial Brass Mfg. Co., 517 S. Racine Ave., Chicago, Ill.

Incandescent
Glowing. The electric resistance welding process is sometimes referred to as "incandescent welding" because the metals are momentarily incandescent at the instant of accomplishing the weld.

Incandescent Process
See "Thomson Process."

"Indianapolis"
Trade name for arc welding machines, flux coated electrodes, welding plates and welding supplies, for street railway joint welding. Made by Indianapolis Switch and Frog Co., Springfield, Ohio.

Indicator
See "Flow Indicator."

Intercept Method for Grain Count
See under "Grain Size."

Internal Strains
Strains left within metals because of unequal cooling. To leave a strain in a piece of metal is to render it liable to break under a smaller load or shock than would normally cause a rupture. Annealing is the logical cure for such strains. See "Annealing."

Induction Apparatus
See "Transformer."

"Industro"
Trade name for welding lenses. Made by Willson Goggles, Inc., Reading, Pa.

Injector Principle
See "Torch Classification."

Inlet Manifold
Inlet manifolds are commonly made of aluminum. They usually arrive at the welding shop with a lug broken off. The first thing to do is to take care of the matter of alignment by clamping lightly to a flat surface, placing a sheet of asbestos paper between the aluminum casting and the surface to which it is clamped. After beveling, tack lightly in a couple of places to keep the lug from being constantly jarred out of position. Follow the procedure outlined under oxy-acetylene welding of aluminum in the chapter on Oxy-Acetylene Welding. Take care that the clamps are not too tight or the metal will collapse when welding heat is applied.

"In Situ" Rail Hardening Process
See under "Sandberg."

"International"
Trade name for welding and cutting torches and regulators. Made by Superior Oxy-Acetylene Machine Co., Hamilton, Ohio.

International Acetylene Association
See "Associations."

"I. O. C."
Trade name for electrolytic oxygen and hydrogen generators and high pressure gas apparatus. Made by International Oxygen Co., Newark, N. J. See Table of Contents, "Catalog Section."

"localine"
Trade name for a granular compound for making solution used in testing the purity of hydrogen gas, in a testing set, using a pipette filled with iron wire. Mixture—one part localine, five parts distilled water. Made by International Oxygen Co., Newark, N. J. See Table of Contents, "Catalog Section."

—J—

Jacks

Jacks are sometimes used in welding operations to aid in compensating for expansion and contraction. See "Preheating" and "Expansion and Contraction."

"Jasco"

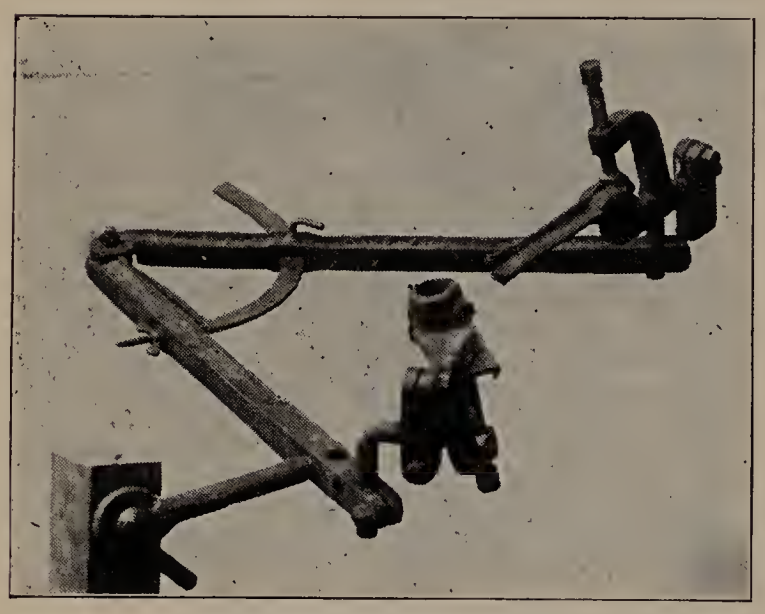
Trade name for cylinders. Made by Janney-Steinmetz Co., Philadelphia, Pa.

Jet

A stream of gas issuing from a torch tip.

Jigs

Welding the side and bottom seams of steel tubs is made considerably easier by the use of simple jigs shown in Figures 1 and 2. They were originally made to use in connection with the welding on tubs and are of such design that they will be found useful in a variety of other sheet metal work. The jig illustrated in Fig. 1 (p. 82) consists of two heavy bars held together by bolting the ends. Figure 3 shows the deep groove cut in the



Jig for Small Repair Work.

top bar to allow the torch to work along the seam, with the bolt holes of the top bar slotted to allow for expansion during welding, and a sketch of the cross section of the top bar. The bottom bar has a small shallow groove directly below the center of the opening in the top bar. This allows the welder to secure thorough penetration and is also helpful in overcoming the expansion effects. The stock is put in the jig as shown in Figure 4, and the side seam welded with the torch. Then a bottom is placed on the frame (Fig. 2), the tub thrown over it, and the bottom welded on from the outside. Fig. 5 gives the shape and dimensions of the tubs for which these jigs were made. The second one is of a more special nature, but the first can be used for welding side seams in a great variety of round, square and rectangular sizes.

Adjustable rollers, made as shown in Figure 6, are very useful in the repair shop as well as in a great variety of production work, and for circular butt welds are often far superior to V-blocks. In the boiler shop, for example, they shorten the process of retipping flues, the set-up for the welding being shown in Figure 7. The old flue and the new end are first set in an angle iron trough to get alignment, and tacked in a couple of places. The welder lays the flue on his set of three rollers, gives the weight a little swing and it wraps itself around

Parts Ready for Welding.

the flue. As he starts his weld he presses down on the pedal and turns the flue just as fast as he wishes. The same principle can be adapted to the welding of crank shafts, axles, and large or small pipes. Figure 8 shows a set-up which illustrates very well the value of the adjustable feature. This a water hydrant, a job which is difficult to keep in alignment on V-blocks because of the different diameters. The welder screws up the rollers for the smaller diameter until the alignment is satisfactory, tacks the break, builds a small preheating fire around the break, and starts welding as soon as the ends are red.

The fabrication of tubular steel products, such as metal tables, stands, etc., calls for as many different jigs as there are shapes and designs to be assembled. The necessary jigs are easily and cheaply made from angle iron, cut, bent and assembled in required designs and used as shown in Fig. 9. The jig is laid upon the welding table and the tubular stock placed in it in the right position. The welder first tacks each joint lightly so as to preserve the alignment reasonably well and then makes a fillet weld around each joint.

See also under "Drills," "Pipe Welding," "Tank Welding," "Sheet Metal" and "Aluminum Utensils."

Journal

The wearing surface of a revolving shaft in a bearing. See "Bearing."

Jump Welding

A type of welding that can be handled on a butt-welding machine. When welding two rods in a jump-weld one piece is held parallel with the opposing faces of the clamping jaws and the other at right angles to the first piece. See "Butt Welding" in chapter on "Electric Resistance Welding."

Fig. 1

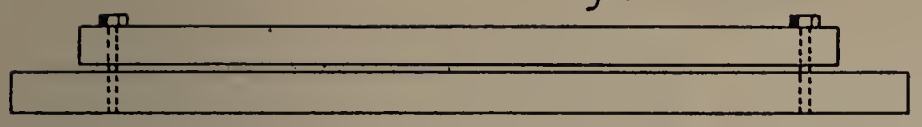
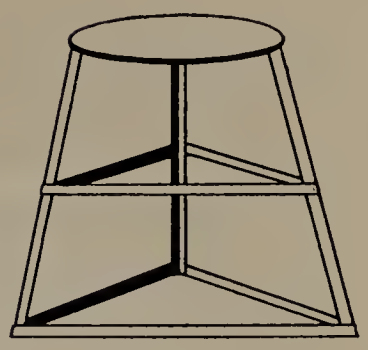
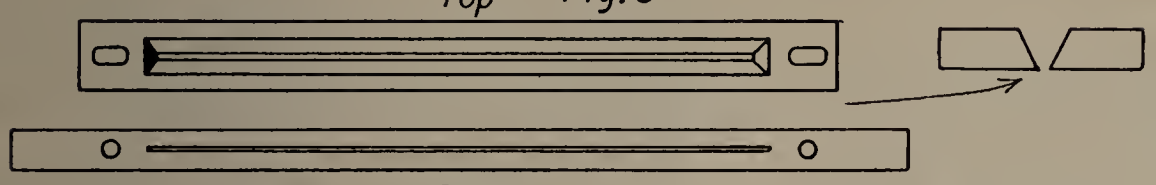


Fig. 2



Top Fig. 3



Bottom

Fig. 4

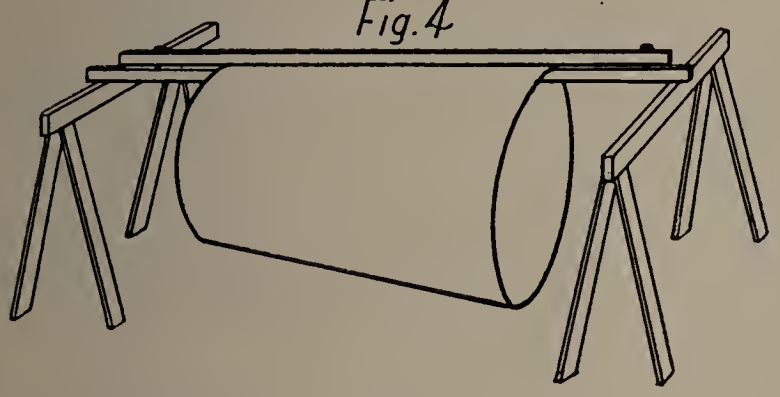
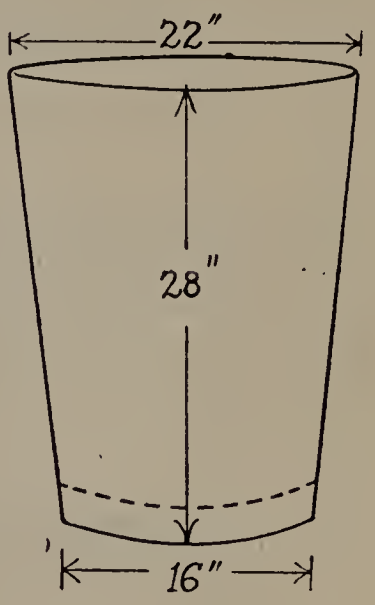


Fig. 5



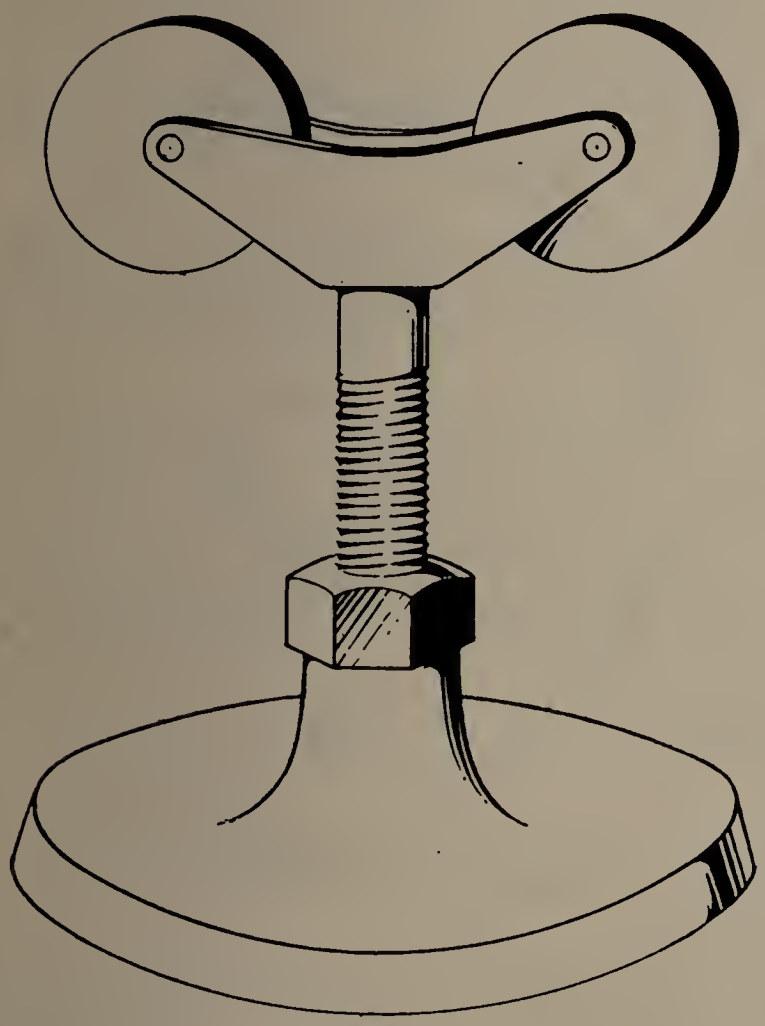


Fig. 6.

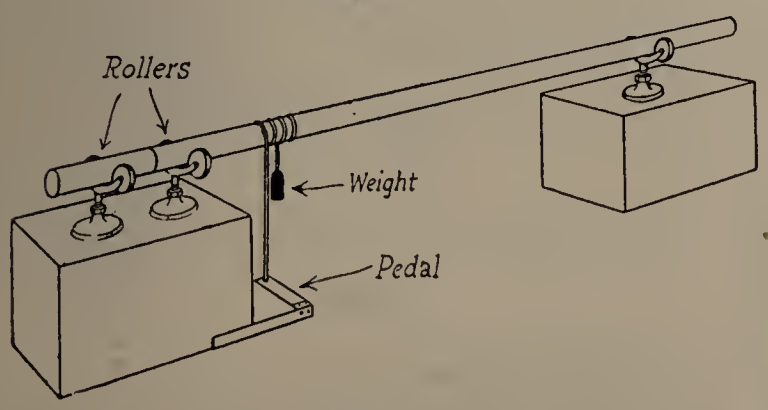


Fig. 7.

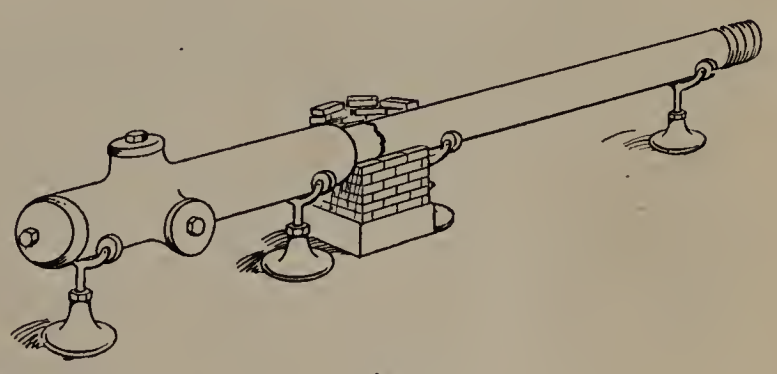


Fig. 8.

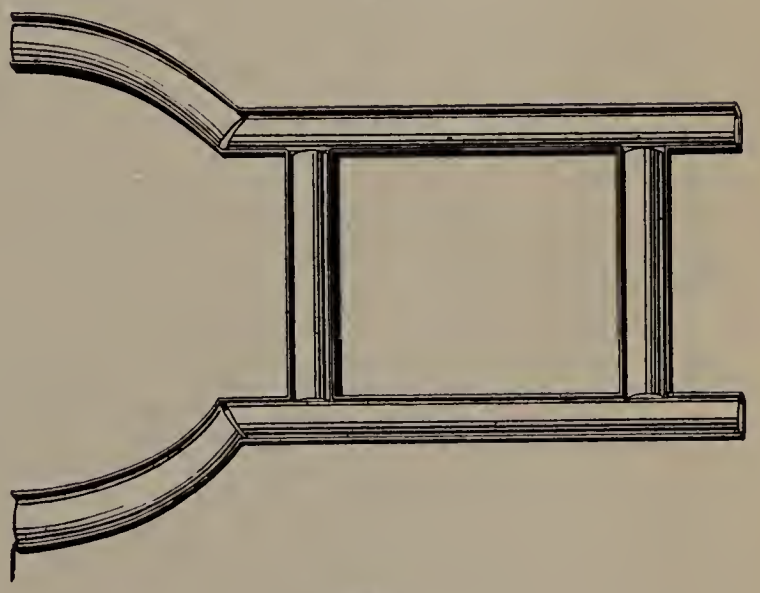


Fig. 9.

Fig. 2

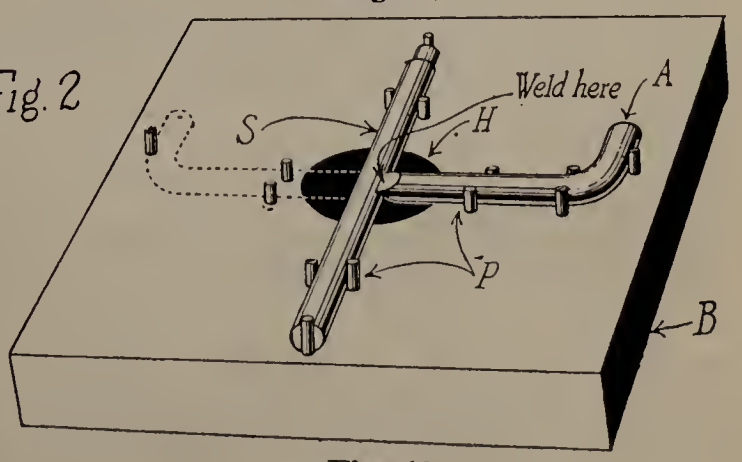


Fig. 10.

—K—

"Karbon Kutting Gas"

Trade name for light hydro-carbon gases chemically mixed to produce the desired heat units for cutting. Made by Louisiana Oxygen Co., New Orleans, La.

"Kathode"

Trade name for welding wire. Made by Lincoln Electric Co., Cleveland, Ohio. See Table of Contents, Catalog Section.

"Kentucky"

Trade name for electrolytic oxygen and hydrogen. Made by Kentucky Oxygen-Hydrogen Co., Louisville, Ky. See Table of Contents, "Catalog Section."

Kerf

The cut or fissure made in metal by the cutting torch.

"K-G"

Trade name for welding and cutting torches, accessories, supplies, regulators, etc. Made by K-G Welding & Cutting Co., 556 W. 34th St., New York, N. Y. See Table of Contents. Catalog Section.

"Kester"

Trade name for self-fluxing solder. Made by Chicago Solder Co., 218 N. Union Ave., Chicago, Ill.

Kilowatt

One thousand watts. This is the unit usually employed in measuring electrical power. One kilowatt is about equal to one and one third mechanical horsepower.

Kilowatt Hour

A volume of work equivalent to the consumption of one kilowatt for one hour. Electric power is always sold by the kilowatt hour (K. W. H.).

"King"

Trade name for goggles, helmets, shields, etc. Made by Julius King Optical Co., 10 Maiden Lane, New York, N. Y.

Kish

Name given to free carbon which forms in the weld when welding grey cast iron with the electric arc. When welding with bare electrodes it causes a dark deposit to form on the weld metal. Chemical analysis indicates this deposit to be iron silicate or slag, which often causes a defective weld by lodging in the weld metal, forming what are called slag "inclusions." To prevent this the surface to be welded may be subjected to a preliminary melting with the carbon arc, or a higher current value may be used to give the desired results.

Kleinschmidt Process

A form of electric resistance spot welding patented in 1898. Its usual application is found in the joining of large pieces of thin metal. The sheets are prepared with raised sections or projections to localize the flow of the current, and pointed copper electrodes are used. Machines for this type of work must provide for the exertion of heavy pressure on the electrodes after the metal is heated to the welding point. Work of this character is described in the chapter on "Electric Resistance Welding."

"K-O"

Trade name for welding and cutting supplies and accessories. oxygen, hydrogen, etc. Made by Kentucky Oxygen-Hydrogen Co., Louisville, Ky. See Table of Contents, Catalog Section.

"Krafyguard"

Trade name for goggles. Made by Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. See Table of Contents, Catalog Section.

"Kromox"

Trade name for chrome nickel steel rod for acetylene or electric welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

K. V. A.

Means volts x amperes ÷ 1000. The term is used only in alternating current practice and is used to represent the apparent load on a generator.

—L—

"Laffitte"

Trade name for welding plates. Made by The Phillips-Laffitte Co., Pennsylvania Bldg., Philadelphia, Pa.

La Grange—Hoho Heating Process

Not strictly speaking a welding process but a method of heating metal which is then welded by hammering. A wooden tank is filled with some electrolyte such as a solution of sodium or potassium carbonate. A plate connected to the positive wire is immersed in the liquid and the work to be heated is connected to the negative wire. The work is then immersed in the liquid. When the piece has reached a welding temperature it is removed and the welding performed by means of a hammer and anvil. Known as the "water-pail forge."

Laminated

Sheet metal laid in layers.

Lap Seam Welding

See under "Line Welding" in chapter on "Electric Resistance Welding."

Lap Weld

A lap weld is one in which the edges of two plates are set one above the other and the welding material so applied as to bind the edge of one plate to the face of the other plate. In this form of weld the seam or lap forms a raised surface along its entire extent. Figure 1 illustrates this.

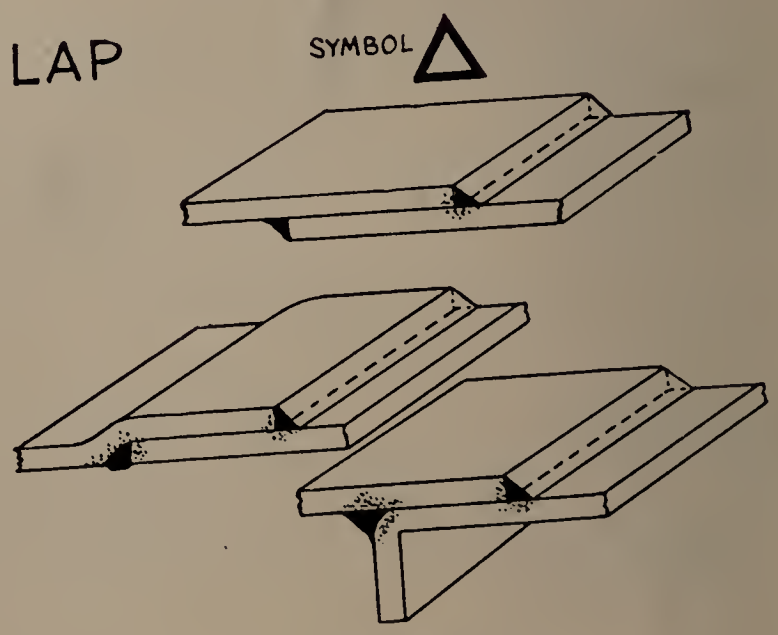


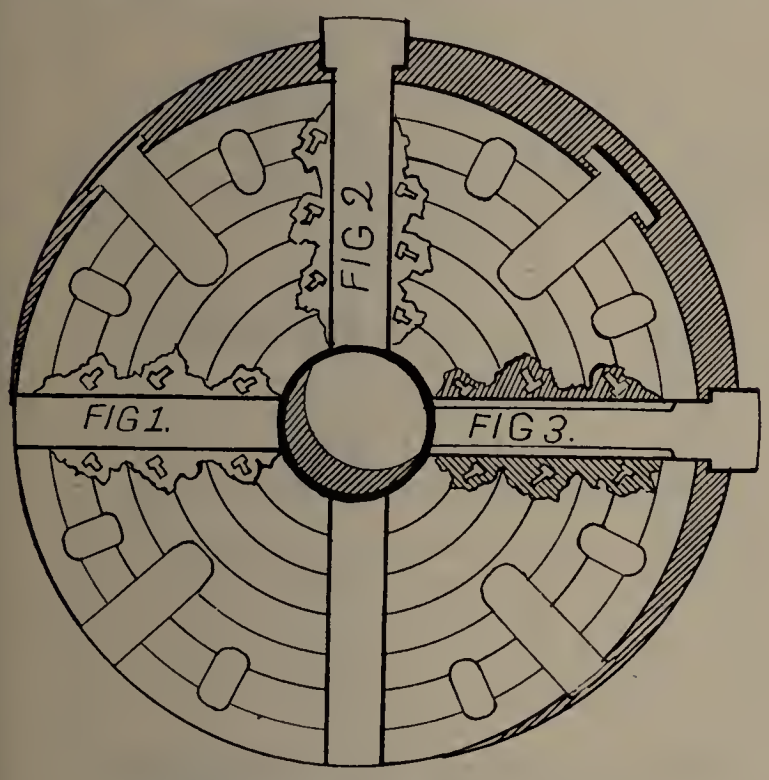
Fig. 1.

Lathe Chuck Welding

To repair broken jaws of a lathe chuck: First have several bolts tapped in the center

of the break nearly at right angles to the surface. Next fit in a piece of carbon ¼-inch thick in the slide way below the breaks (Fig. 2). It forms a bottom for the welded iron, at the same time leaving a good smooth edge to the underside of the jaw. Next fit on top of this another carbon shaped as Fig. 3. This is so each side can be welded separately, not allowing the weld to extend clear across in one solid mass, which might set up a strain or warp. Should break extend to center hole of chuck, then brace up a piece of carbon or brick in the hole against the ends of the breaks, filling up uneven spots with fire clay so you can puddle iron without having it run out of the end of the slot. See that the center air hole is not entirely stopped up, as air space is needed in the center for combustion.

Build a furnace out of fire brick supporting chuck laying flat face up on four bricks on edge, see that the bricks support chuck on the thin parts, allowing the four thick parts fully exposed to fire. After laying first layer of brick of furnace, work the charcoal well into the center all around so as to get as even heat as possible. In firing up with the welding torch see that the charcoal is burning everywhere, and not in spots. You will have to look it over occasionally and sometimes have to use torch several times. This must not be neglected if you are to have a job not warped. Do not heat chuck hotter than when it commences to show a dull red in shadow, not in strong light. It is much more handy to have the asbestos lid on furnace in two pieces. They can be parted at one point of weld, holding down the heat and not exposing chuck to cold



Steps in Welding Lathe Chuck.

air on top. After weld is completed, have enough dry engine sand ready to completely bury the chuck. It smothers the fire, cutting off direct heat from the bottom and holding it down on top. It is now as near to the condition of a regular casting in sand as can be had. It is advisable not to take it out under 18 hours. When chuck is taken out and laid on a level slab it should not rock a bit.

"Lawrence"

Trade name for patented process for repairing scored cylinders. L. Lawrence & Co., Newark, N. J.

Lead Burning

"Lead Burning" is the very poor name which has affixed itself to a very interesting and comparatively little known process of autogeneously uniting lead surfaces. Lead is not "burned" during the process, unless the job is improperly done. If any of the lead is burned the result is inferior work or increased cost of the operation. Lead united by "burning" is joined together in almost exactly the same manner that steel parts are joined by the oxy-acetylene welding process.

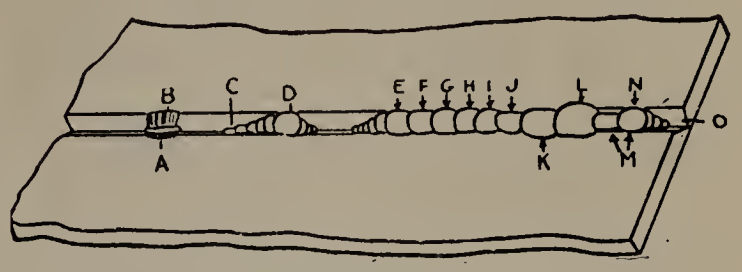


Fig. 1.

When welding lead surfaces the man who has had experience with oxy-acetylene welding on other metals will have little trouble after he learns that much less heat is required for uniting lead. The tendency of the oxy-acetylene man is to overheat and really burn lead, until he becomes accustomed to using hundreds of degrees of heat, instead of thousands.

The beginner in lead work has many things to learn, but each is very simple, easily acquired, and then requiring only lots of practice in order to make the fingers obey the brain quickly and cunningly.

The preparation of lead surfaces for air-acetylene welding is about the same as for steel. In lead work the metals are nearly always comparatively thin. There are few heavy masses of metal to be united. The first thing to do, after the surfaces have been placed in position, is to bevel or chamfer them, as shown at O, Fig. 1. Unless the lead be very thin, indeed, do not try to weld it without first beveling the edges, in order that the welding may be commenced at the bottom, instead of at the top. When the attempt is made to weld thick lead sheets without beveling them, it is found a hard task to drive heat enough to the lower edge of the metal to fuse it there. Driving heat down through a pool of molten metal is not a very satisfying operation, and the welder never can be sure that he has formed a good weld at the bottom. And this point is very important where good work is required.

Having adjusted the flame until it is a very hot, intense little point, proceed to heat the sheets to be united, commencing say at A, Fig. 1, where the heat is allowed to play into the chamfer until both surfaces, at A and also at B, have become heated to the point of becoming liquid. Should more heat be applied, lead would actually run down into the bottom of the chamfer. In fact, a very small puddle of metal is there to be seen.

But at this point, when the chamfer on either sheet has become liquid clear up to the edge of the solid sheet, and even for a hundredth part of an inch into the solid metal, then arrest further melting of the sheets by introducing a "solder stick," consisting of a strip of the lead which is to be joined together. Strips cut from waste pieces may be used for "solder sticks."

Arrest further melting of the sheets by putting the solder stick into the flame and melting a portion of lead into the chamfer, as shown at C, more and more lead being melted in, until the chamfer is completely filled, as at D. During the time of melting in the extra lead, close watch must be kept of the metal which is being melted into the chamfer, also of both edges of the sheets to be joined, and each must be kept at a temperature which will keep their surfaces liquid and flowing into each other

freely. At the same time the heat must be so very cunningly and cleverly regulated that neither surface shall be overheated or melted too much. Here is where the skill of lead welding comes in. Playing the torch flame upon the work just the right length of time, snapping it on and away, as best will keep things heated exactly right, and so the metal from the solder stick will unite and flow into the melted metal of the chamfers—that is what must be done, and is where skill and experience counts for everything.

As soon as one little spot, an eighth or perhaps a quarter of an inch has been built up in the chamfer, the operation must be repeated again and again, as shown at E, F, G, H and I. It is good welding when the puddles are all of the same size, and all even on both edges, and at the same time perfectly fused into both sheets.

Perhaps a puddle will come out like that shown at J. Here the union is perfect on one side, but not on the other. The top side evidently did not get heated hot enough, the chamfer did not melt, and it is very likely that the metal from the solder stick did not unite perfectly with the metal of the sheet. This is one of the great causes of leaks in welded lead work.

At K a puddle is shown which has been melted too far into the near sheet, but which is seemingly all right against the far sheet. Work of this kind looks bad, but it is solid work, and will not leak. It is far preferable to puddle J or M. Puddle L shows one which has been melted too far into either sheet. It looks bad, but is solid, and aside from its bad looks it represents a waste of time and gas. The beginner should look out for puddles of this kind, which usually are caused by allowing the flame to play too long against the sheets, due probably to inattention to the work in hand, or to pure carelessness. It should be watched for and corrected by the welder who finds himself permitting puddles like L in his work.

Puddle M is bad, very bad. It may be that the metal is solid with both sheets, but being low, the puddle will always be looked upon with suspicion when it is left in this shape, and a good welder will not leave a puddle in that way.

Puddle N is apparently good, but really, one of its kind is not to be trusted. Note that it is nearly round. Both chamfers are melted in the center of the puddle, but there does not seem to be any length to

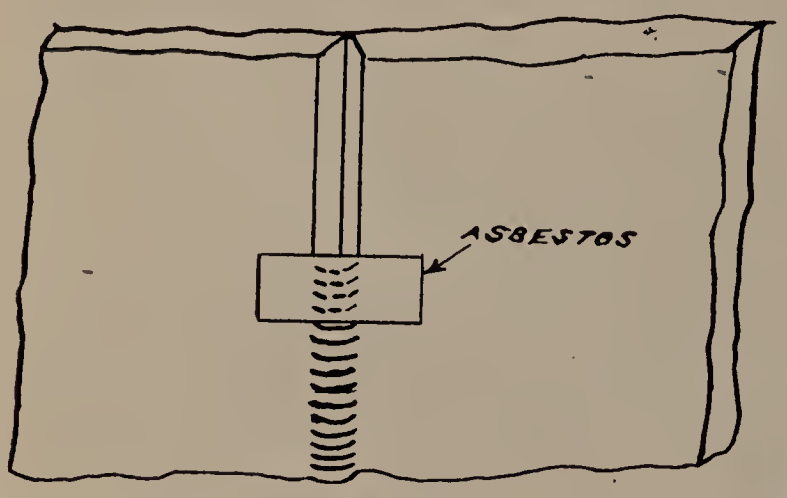


Fig. 2.

the union. Just a round puddle, and it is very likely that there will be a leak or two between this puddle and the adjacent ones. It is very important that the sides of the puddles be well united with both sheets along the entire length of each puddle.

Vertical work presents a few complications not met with horizontal welding. The molten metal must be held in place with a sheet of asbestos held tightly against the surface, and protruding a short distance above the point being welded. Fig. 2 illustrtes how such a weld is performed. The chamfer is made as in horizontal seams and the work is usually commenced at the bottom. The puddles made in vertical work will usually be thicker than those in level work, for the asbestos permits the metal to pile up somewhat. This tendency should be curtailed as much as possible for thick puddles generally result in leaky seams. The puddles should always be made as small as possible. It is probable that some lead will drip down the seam as the height increases, but such metal as may run from beneath the asbestos may be disregarded till the entire seam is completed, when it can easily be removed. Here again, skill can be acquired only by practice and careful observation.

Storage Battery Work*

The skill of lead burner is also called for in the assembly of a storage battery. After the plates are formed they must be burned to the pillar straps. The entire system is held rigidly in an iron frame. (See Fig. 3.) A mold is formed around the pillar straps with strips of steel to prevent any slopping over of the metal. Then the torch is manipulated so as to melt the protruding lugs as quickly as possible. To insure complete union throughout, the metal should be agitated with an iron poker while applying the heat. If any holes form on the surface they must be filled with stick lead. Great care must here be exercised to insure complete fusion of the entire depth. Incomplete fusion will effect the quality and performance of the union.

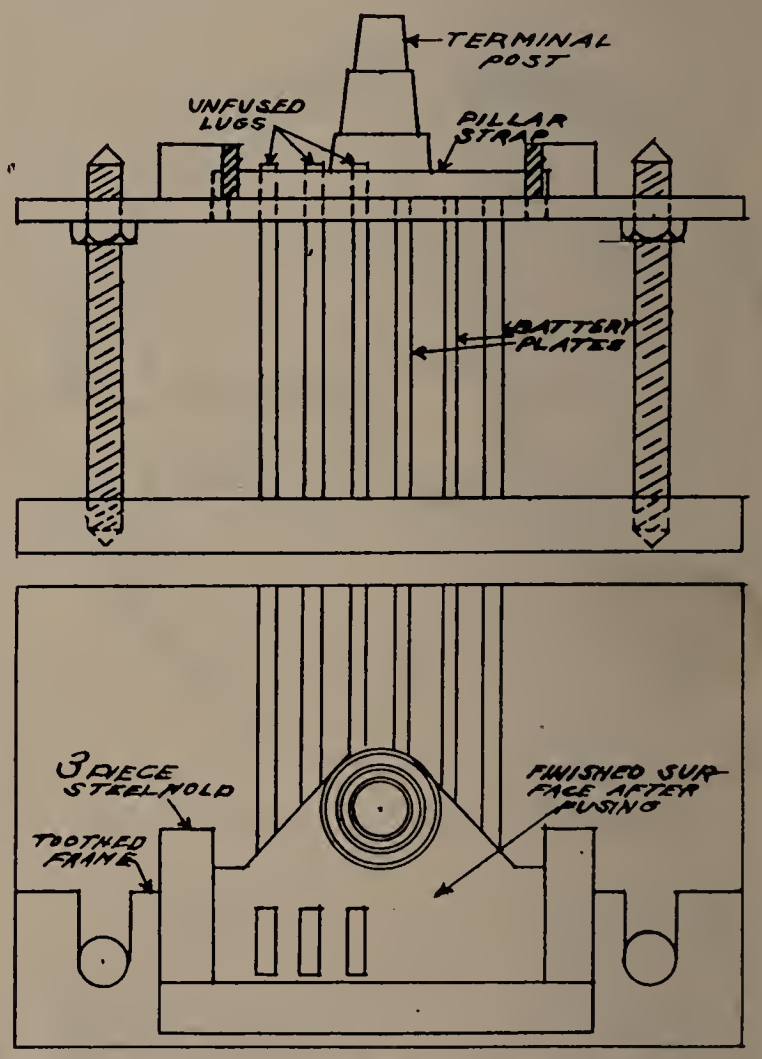


Fig. 3.

By means of the torch and a little stock metal, battery plates with broken lugs can be quickly rendered serviceable again. Very often, in assembling a battery, the connecting lugs of the plates are broken off. It is a very simple matter to rebuild these lugs with the aid of a mold made of steel strips. The arrangement is shown in Fig. 4. The

**Written by P. Unger for The Welding Encyclopedia.*

entire outfit is laid upon an iron plate, and the lug built up to its normal height.

Not until the battery has been completely assembled is there any further need for lead burning. The cell connectors are hammered on, joining the positive pole of one cell to the negative of the next, so that the connecting straps are level. Before applying the torch the cells should be well ventilated and an absence explosive gases be assured. This is done by playing the flame down into the cell momentarily. Then a strip of asbestos is placed over the vent holes, in order that no dripping lead or other impurity may fall into and injure the cell. Bring the flame down vertically so that the extremity of the cone bears directly on the edge of the post. First melt together the edge of the hole and the top of the post. Then add stick lead, if necessary, to build up the post. Finally burn to a smooth level finish. Be sure in bringing the flame down that the envelope does no preheating. This is important as it will often cause the lead to drip over the side. It is here that the real ability of the lead burner is shown. The operator can be guided only by experience and careful observance as to how, when and where to apply the flame during this procedure.

If, however, in spite of all precautions some lead does run over the side, it should be

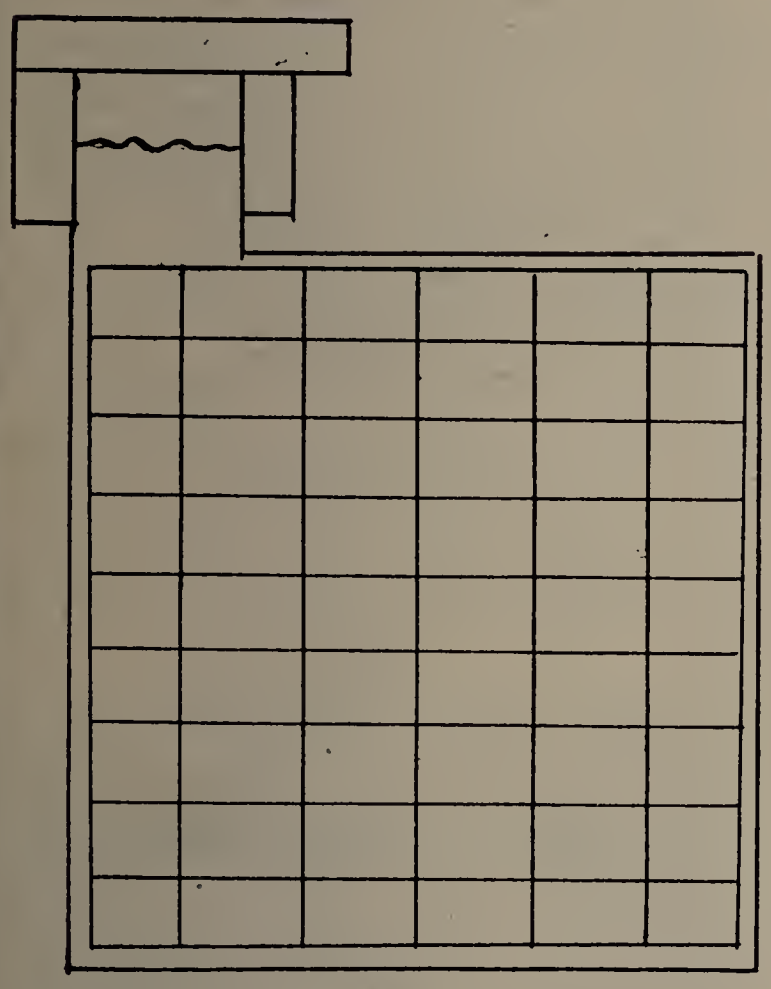


Fig. 4.

removed with a putty knife. By surrounding the lug with an iron ring as a mold, the post is then rebuilt with stick lead.

"Lejon"
Trade name for Swedish iron acetylene welding rods. Made by B. Dieden & Co., Inc., 50 Church St., New York City.

"Lekkote"
Trade name for coated iron electrodes for arc welding cast iron. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Lektrox Swedox"
Trade name for electrode wire and rods for general electric welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Levin"
Trade name for electrolytic oxygen and hydrogen cells, generators, etc. Made by The Electrolabs Company, 2635 Penn Ave., Pittsburgh, Pa.

"Liberty"
Trade name for aluminum solder and special welding metals. Made by Liberty Welding and Mfg. Co., 4200 Grand River Ave., Detroit, Mich.

"Lightning"
Trade name for flux. Made by Mutual Auto Specialties Co., 5031 Liberty Ave., Pittsburgh, Pa.

Lime
The temperature of acetylene generation often causes a quantity of carbide lime which is carried by the gas. This lime dust passes freely through water, but fortunately the quantity usually present is small and it can easily be removed by any good chemical purifier. Its effect on welds has not been carefully studied, but cases have often been reported of the dust having choked up the narrow passages of the torch, while some authorities hold that it is often responsible for the "spitting" of the torch.

Line Welding
Same as "Seam Welding." See chapter on "Electric Resistance Welding."

"Lincoln"
Trade name for electric arc welding equipment. Made by The Lincoln Electric Co., Cleveland, Ohio. See Table of Contents, Catalog Section.

"Lincoln"
Trade name for arc welding dynamotor for street railway track joint welding. Made by Rail Welding and Bonding Co., Cleveland, O.

"Lincoln High Visibility"
Trade name for welding glass for electric arc welding. Made by The Lincoln Electric Co., Cleveland, Ohio. See Table of Contents, Catalog Section.

Lincoln Process
See chapter on "Rail Joint Welding."

"Linde"
Trade name for liquid air oxygen. Made by Linde Air Products Co., Carbide and Carbon Bldg., New York, N. Y. See Table of Contents, "Catalog Section."

Linde-Frank-Caro Process
Water gas process for producing hydrogen. Steam is passed through incandescent coke; the oxygen forms carbon dioxide with the carbon in the coke and the hydrogen remains free, and is separated from the rest of the gases by compression and cooling.

Liquefaction
Reduction of gas to a liquid state by compression and refrigeration.

Liquid Air Process
A method of generating oxygen. See "Oxygen."

Locomotive Cylinders
When welding with acetylene, the cracked or broken cylinder is V'd out to a 45 degree angle and the opening left from ⅛ inch to $\frac{3}{16}$ inch on bottom of the crack. A frame is then built around the cylinder which is heated to a cherry red heat with a charcoal fire before starting to weld. In using an alloy cast iron rod for filler, care must be taken not to chill the iron or it will be hard. After the weld has been completed and has cooled, the furnace is taken away and the cylinders bored or trued up.

In welding engine cylinders with electric metallic arc, all cracks or broken parts are V'd out or beveled to a 45 degree angle and studs applied. The size of stud is used according to the thickness of the casting. Where the casting is one inch or over it is customary to use a ¾-inch or a ⅞-inch stud. These are placed about two inches apart, using one row in the crack and two rows outside, one row being on either side

of the crack. Wherever a new piece is set in to replace a piece broken out, it is customary to use forged steel, with studding applied only to the cast iron. In making the weld, a light layer is placed around each stud first. Then the layer is put on where the weld is going to be applied, after which you have steel to steel to weld.

To prevent leaks from forming next to the cast iron chip an irregular groove along the face of the bevel above the studs,[1] and in the case of bad breaks another groove on the surface near the bevel. Lay beads across this groove, filling it as well as possible. The groove forms a steam trap and eliminates leaks. Avoid the use of compositions recommended for "puttying up" leaks in bad welds. Make good welds instead. See "Arc Welding Cast Iron," in chapter on "Electric Arc Welding."

Beveling is an important part of the repair, and to get maximum solidity on the inside it is well to bevel as much as possible on the inside. It is also good practice to reinforce the weld about an inch on the outside. In some cases this reinforcing can be helped by applying small wrought iron straps over the break and fusing them thoroughly into the puddle.

The repair illustrated in the accompanying photograph was made by the metallic electric arc process. The parts broken from the cylinder had been so completely destroyed that it was necessary to recast an entire new portion. The new cast section was studded with a large number of small steel studs, as was also the unbroken portion of the cylinder. These studs are deeply grooved about a half-inch above the surface so as to be weakened; then in applying one of them a wrench is used on the end and as soon as the thread has been turned as far as possible into the tapped hole further efforts applied to the wrench break the stud at the weakened point. The

Locomotive Cylinder Weld.

result is a clean, bright, easily welded surface. This differs slightly from the usual practice in studding, as may be seen by referring to "Studding" in Part III of the chapter on "Electric Arc Welding."

Brazing Locomotive Cylinders

It frequently occurs that the time and labor required for preheating and cooling a cylinder can be saved by using the bronze rod instead of following the regular welding procedure. To make a good strong bronze repair job, the broken pieces should be bevelled to a 45° angle and holes drilled and tapped on the inside of the bevel for ½-inch tap bolts. These bolts should be screwed in far enough so that about ¼ inch is left from the under side of the bolt head to the face of the bevel. At the outside of the bevel, chip off a thin section about $\frac{1}{16}$ inch thick and about 1¼ inches back from the edge of the V. This will leave plenty of surface for tinning the casting. After this preparation is made, set the broken parts in place and tack them securely. Close the cylinder heads with iron plates and start an oil torch burning inside the cylinder. When the cylinder gets too hot to touch, it is time to start welding. Heat up a small area (about ½ inch) and put a thin coating of bronze over it, then bronze over the adjacent area and so on. After a good portion of the surface is coated in this manner, the regular bronze weld can be made but the casting should always be coated with bronze at least an inch ahead of the area that is being welded. This type of repair can, with a little practice, be made to stand up for months of hard service and it serves the purpose of putting a locomotive back into operation with the least possible delay.

Locomotive Frame Welding (Acetylene)

When welding broken engine frames the frame is trammed and leveled, after which it is V'd out about 45 degrees on both sides with the acetylene cutter. It is then chipped to remove all scale and burned material. The next step is to expand the frame about ⅛ of an inch in order to take care of contraction. To secure this expansion use a charcoal fire on the rail that is not broken, and as this expands, it will open the one in which the break is located. Two welders are then put on to weld, one on either side. When they get one layer welded on, they take an air hammer and bob it to get the scale and dirt off before starting another layer and continue in this way until the frame is welded flush. The welded joint in the frame is then re-enforced by use of ⅝ inch or ¾-inch round mild steel bars which are put across the weld and extend two inches on either side of it. These bars are spaced from an inch to 1¼ inches apart and are welded in solid where possible. Bars placed in this manner greatly increase the tensile strength of the frame at the welded joint. In welding single rail frame, the rail

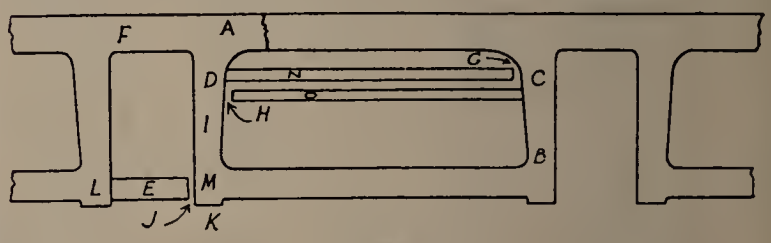


Fig. 1.

is expanded on the opposite end to get the expansion where the break is located. Afterward the weld is made in the same manner as in the case of the two welded rail frames.

Two methods of obtaining expansion on broken locomotive frames have been suggested when the break is at (A) as shown in sketch:

First. Drop binder from pedestal (K); then set a screw jack under binder fit (K); tighten up a sufficient amount to get frame in proper alignment.

Second. Cut a piece of bar stock of any kind that has cross sectional area enough so there is no danger of upsetting or bending, place it as shown in sketch at (E) between (L) and (M) with space enough at (J) to admit a wedge (the wedge used for this should have not more than $\frac{1}{16}$ taper to the inch and made of carbon steel of about common spring grade).

Drive wedge at (J) and watch the break to see if it opens, if not start a wedge at break (A); drive both wedges at the same time. When sufficient expansion is obtained remove wedge from break, then bar (E) will hold expansion. Some welders advocate cutting jaw at (I) to get exponsion, but I have found by heating this point to a dull red heat it can be sprung enough to get the proper amount of expansion. Then after the weld is finished heat this section to a

[1] *See "Grooving."*

good red heat, so it will straighten up when the weld cools. This saves one weld also considerable gas, time and welding material, as I think everybody concerned will agree that the least number of welds you have, the better.

Third. When the above method fails place a bar from (C) to (D); drive wedge at (G), usually with bar (E) and bar (N). We can get the proper amount with heating at (I), but if this fails, place the next bar (O) just below bar (N) with about 1½-inch space between the bars, then drive wedge at (H) with two heavy hammers, drive (G) and (H) at the same time. When this will not obtain the proper amount, place a piece of asbestos paper between bar (N) and (O), then take a large welding head and play the flame on bar (O) at the same time driving wedge (G) as the expansion opens up the break, using care not to get the bar hot enough to upset. When you think you have obtained all the expansion possible from bar (O) then take a water hose and cool bar (O) off, reset wedge (H), drive up hard and repeat the heating operation as many times as is necessary to get the desired amount of expansion.

Failures in frame welds are caused by incompetent operators, use of poor grade of welding wire, improper spreading and failure to remove rods and riggings adjacent to the weld which interferes with the welder getting easy access to the work.

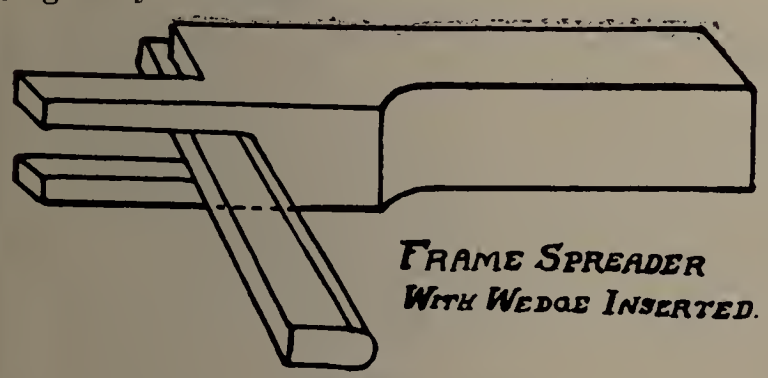


Fig. 3.

The following table on expansions gives the approximate figures for various classes of frames.

Size	Location of Break	Expansion
3"x4"	Top or Lower Rail—Pedestal	¼"
4"x4"	Top or Lower Rail—Jaw	5/16"
4"x4½"	Top Rail—Pedestal—Jaw	11/32"
4"x5"	Top or Lower Rail—Jaw	⅜"
5"x6"	Top Rail—Jaw	13/32"
6"x8"	Top Rail—Jaw	7/16"
6"x9"	Top Rail—Jaw	½"

An easy way to spread a frame is by using a spreader, as shown in the Fig. 3. This can

Fig. 4.

be placed in most any part of the frame by cutting a slot in the fracture to allow the use of a wedge. Then by alternating the sledging first on the wedge in the frame, then to the wedge in the spreader, it is not difficult to obtain the desired expansion. The objection to using jacks is that they are apt to settle if a heavy strain is left on them. To hold the heat during the welding operation, use 1½-inch lagging, wired to the frame, as shown in Fig. 4. After the weld is completed it can be shaped up with a flattening tool and a sledge, lagging applied again, and the weld allowed to cool slowly. In cases where it is hard to get the required expansion, the spreader need not be released until the weld is finished.

Fig. 5.

But if the frame is easily spread, it can be released when the weld is three-quarters finished. Take plenty of time to allow the metal to settle in quietly. It is usually necessary to use more than one welder on the job.

Locomotive Frame Welding (Electric)

When welding locomotive frames with the electric arc it is not usually necessary to preheat in order to compensate for the contraction of the added metal. This contraction effect is usually so slight that it can be provided for by using a jack or wedge to force the abutting members apart before welding. The greatest free space between frame points should be at that end of the opening toward which the welding is progressing. The points of opening should be from ⅛ to 3/16-inch, according to the size of the frame. It is customary to provide a reinforcement on frame welds by welding a small rod a little less than 1 sq. in. in the cross section on the outside and across the line of welding. A 1-inch plate is usually welded to the bottom surface of the broken

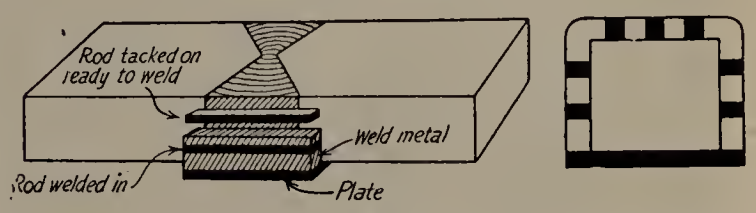


Fig. 2.

section, as indicated in the diagram, which shows the broken members half welded in this manner, and also the cross section of the completed repair.

In some shops it is common practice to use triangular shaped filler plates to help fill up the large opening made by the 90 degree bevel. A ¾-inch hole is drilled in the center of these plates and plug welds made over them. Reinforcing rods are not usually applied in connection with the filler plates, but the weld itself is well reinforced. In fact the base of the triangle should be allowed to project about ½-inch outside the surface of the broken member.

Frame Welding ("Thermit")

See chapter on Thermit Welding.

Long Arc

See chapter on "Electric Arc Welding."

Longitudinal Seam

The seam which extends lengthwise.

Low Pressure Principle

See "Torch Classification".

Low Spots
Unfilled spaces in the metal caused by moving the torch too fast or unevenly.

"Loxco"
Trade name for oxygen, hydrogen, karbon kutting gas and acetylene, manufactured by the Louisiana Oxygen Company, New Orleans, La.

"Lucy Jane"
Trade name for preheating torches. Made by Macleod Co., 2220 Bogen St., Cincinnati, Ohio.

Lugs
Broken lugs on intake and exhaust manifolds should be handled along the same lines as should cylinder lugs by welding inside first, then across the outside, finishing up by welding the cracks in the face, allowing to cool and then grinding out inside with a portable grinder for piston clearance.

"Lynite"
Trade name for an aluminum alloy. Made by Aluminum Casting Co., Cleveland, Ohio.

—M—

"Macleod"
Trade name for welding and cutting apparatus, accessories, preheating equipment, etc. Made by The Macleod Co., Cincinnati, Ohio.

Macrograph
A graphic reproduction of any object which has been magnified not more than 10 times.
When it is desired to indicate that it is a photographic reproduction, the term "photomacrograph" is employed.

Magnetic Oxide of Iron
The oxy-acetylene cutting process leaves an oxide deposit called magnetic oxide of iron.

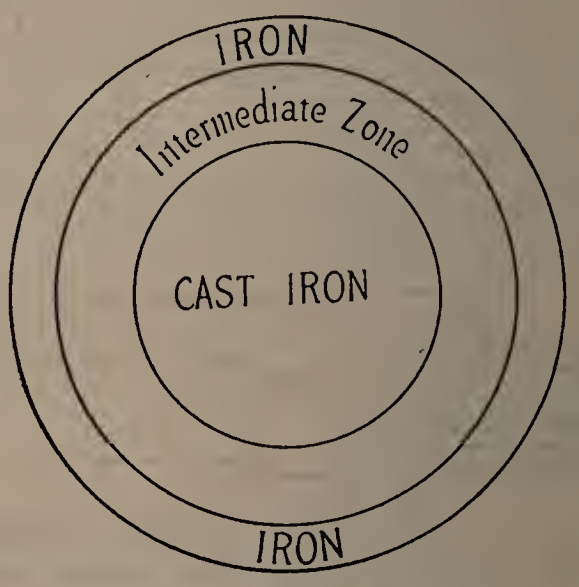
Magnification
The ratio of the size of the image to that of the object, based on linear dimensions, and generally expressed in "diameters," thus ×100 or 100 diameters.

Malleable Iron Welding*
Unlike most other cast materials, malleable iron possesses its characteristics not only on account of its compositions, but also on account of the heat treatment to which the castings are subjected in the process of manufacture.

As originally cast, this material is hard and brittle, and has a white structure. Its appearance under the microscope is indicated in Figure 1. In this figure the white ingredient is iron carbide (Fe3C), the greyish background being a solid solution of this carbide in iron. All carbon present is in the combined form.

In the annealing operation the appearance and structure of the hard iron is entirely changed, the resulting product being resistant to blows under the hammer, and of a black velvety or grey silky structure.

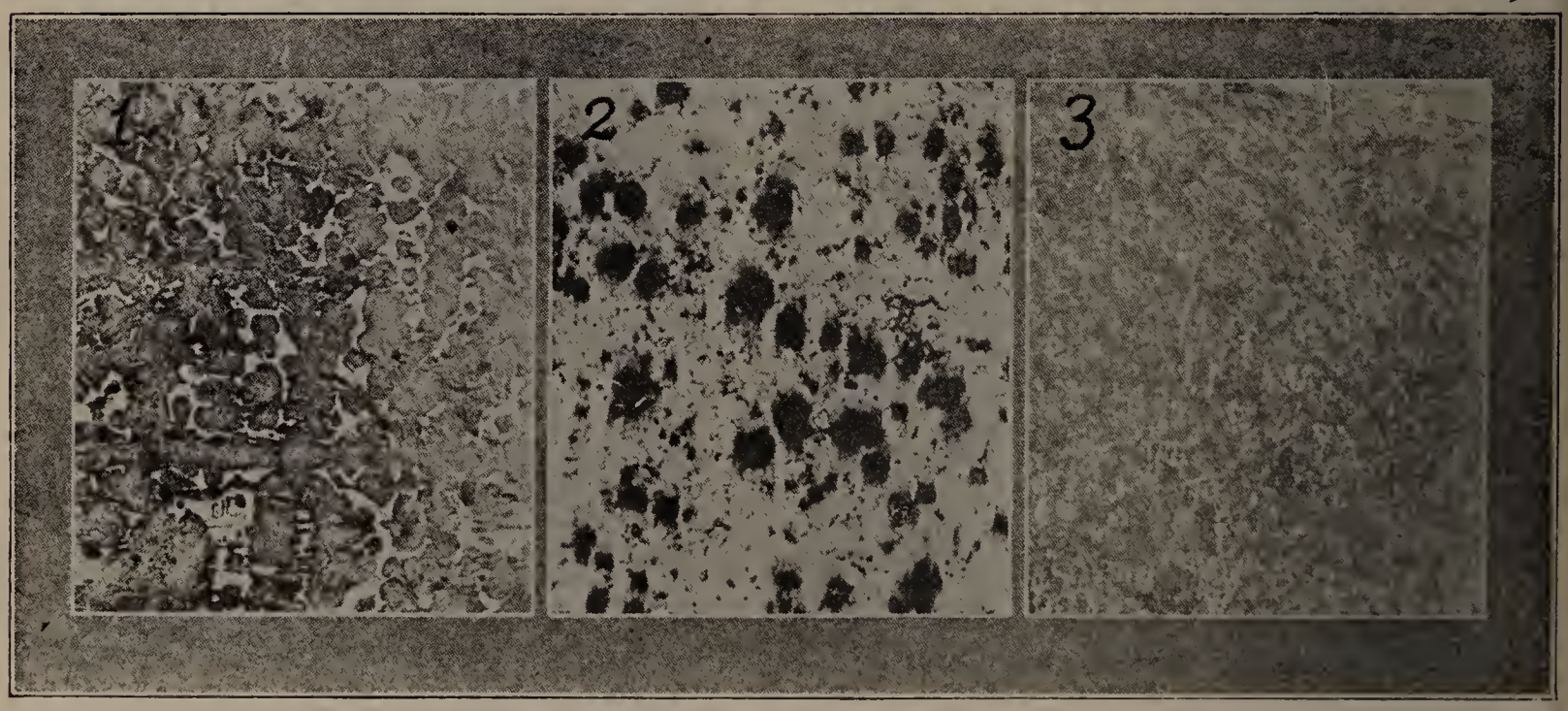
Under the microscope malleable iron has the appearance as shown under Figure 2 in which the rounded dark areas are free carbon in the "temper" form, the white background being a mass of nearly pure iron in the form of separate grains. The latter



Structure of Malleable Iron.

structure is derived from the former by the heat treatment to which the metal is subjected in the annealing. This heat treatment, in general, consists of raising the temperature of the product to somewhere between 1,500° and 1,700° F., maintaining this temperature for a period from ten to forty hours, and then allowing the casting to cool very slowly, usually at a rate not more than 10 an hour. The exact time and temperature vary somewhat in different plants, and under different circumstances.

If malleable iron is heated to a temperature above the critical point, all, or part of the effect of the annealing is destroyed, depending upon how high a temperature the material has attained. Such re-



*Written by H. A. Schwartz for The Welding Engineer.

heating unless followed by cooling at least as slowly as is the practice in the original annealing will cause the casting to again become hard and brittle, approximating in character, at least to some degree, the properties of the original hard iron casting.

The welding of this material involves, necessarily, the heating of a part of the article to be welded to a temperature up to its melting point, and is therefore accomplished with greater difficulty than will be found in the welding of any other similar product. Generally speaking it is the practice to weld a material, using as a filler a material as nearly identical with that of the article to be welded as may be possible.

In Figure 3 is shown a microphotograph illustrating what happens when an attempt is made to repair a malleable casting by welding malleable iron into the section to be repaired. The photograph represents a section of the weld corresponding to the material derived from the molten filler rod. This section instead of having the structure normal to malleable iron as shown in Figure 2, has a micro-structure differing from that of hard iron shown in Figure 1, only in that it is finer grained. In other words in the process of melting, all of the temper carbon of the malleable iron has been reconverted into the combined condition in which it existed in the original hard iron casting. The structure is close grained merely because the small weld freezes more quickly than a fair sized casting. The material in the weld has the properties one might expect from the micro-structure, in that it is as hard and brittle as the unannealed casting, therefore this method of procedure is a total failure.

It may be argued that since the body of a malleable casting consists mainly of nearly pure iron, a weld might be made using Armco iron, or a Swedish wrought iron for the filler.

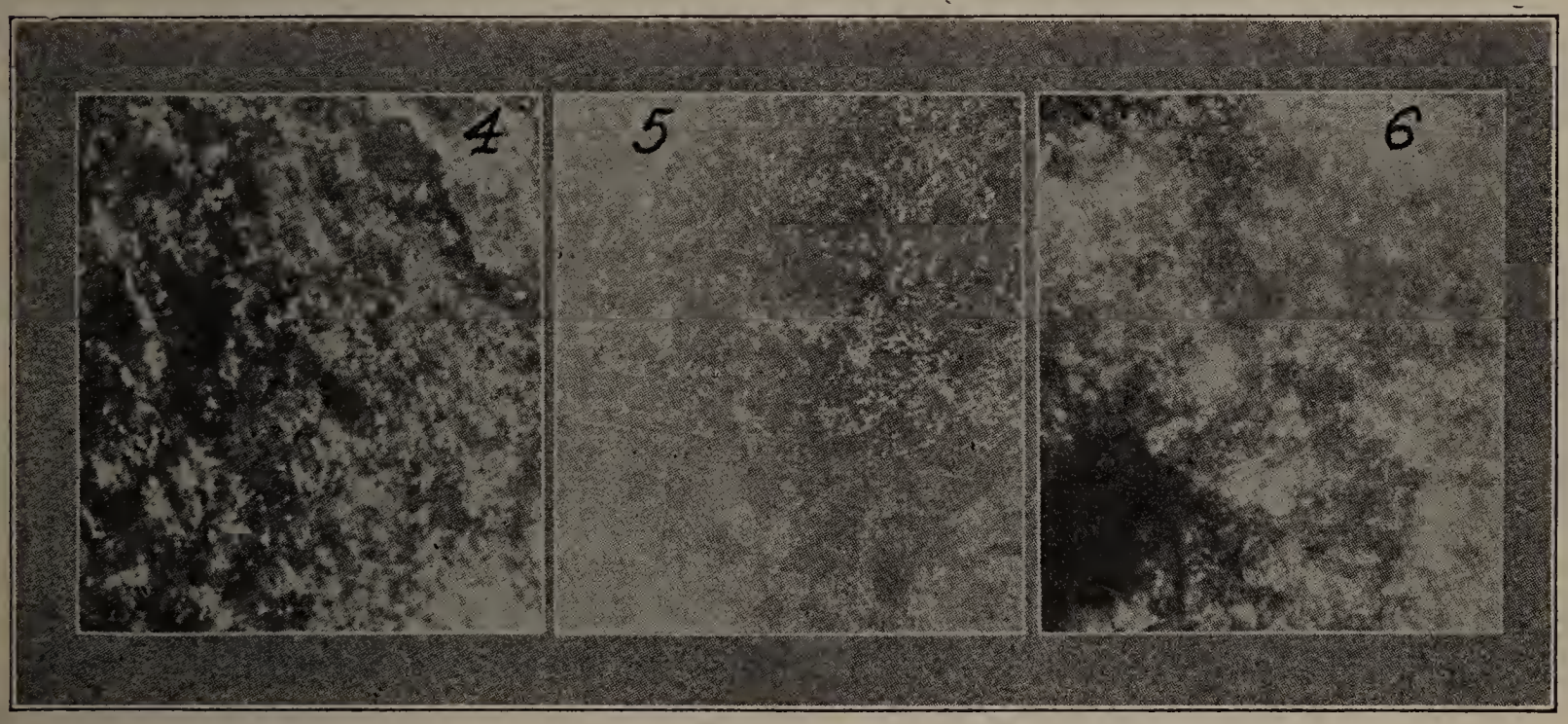
Figure 4 is a microphotograph of the material filled into a weld, using Armco iron. It will be seen that this structure has not the granular structure of pure iron which can be seen in the background of Figure 2, but has a confused greyish appearance due to the fact that the pure iron in the molten condition has absorbed carbon from the more highly carbon bearing malleable castings with which it is in contact. It approximates in properties fairly hard steel, and is much too hard and brittle to serve as a welding material in the repair of malleable castings which are in general intended for service involving resistance to shocks and blows.

Welding malleable iron with soft iron is therefore impracticable, since it is impossible to prevent the contamination of the molten pure iron by the carbon of the welded casting.

Since grey iron castings can be welded using filler rod of extremely soft cast iron (very high in silicon) the suggestion has occasionally been made that it should perhaps be possible to patch malleable castings with grey iron. The thought was that even though the grey iron casting might be more brittle than the malleable, still it would be soft enough for machining, and particularly in relatively unimportant places might have sufficient strength to render its use possible.

In micrograph 5 is shown a section of a weld made in a malleable casting, with grey iron. The grey iron did not preserve its softness, quite possibly due to insufficient silicon, and is present in the form of white cast iron. It shows white areas of iron carbide on a greyish background essentially similar in character to the white cast iron of Figure 1, and the remelted malleable of Figure 3. Even if this difficulty were overcome, by securing grey iron so high in silicon that it would remain graphitic in spite of the quick cooling, incident to its use as a filling material in welding; another difficulty would be encountered.

It will be seen in Figure 5 that the structure of the malleable iron to which the grey iron has welded, has been materially changed. Instead of having the appearance shown in Figure 2, the background has become very dark, so dark that the masses of temper carbon are almost invisible, though they still exist.



This is due to the reabsorption of some of the temper carbon by what was originally the pure iron matrix of the malleable casting, converting the latter into a steely mass similar to that formed in the weld shown in Figure 4.

Figure 6 shows this structure at a higher magnification, and permits some idea to be formed of the ingredients present. This same reabsorption of carbon with a consequent embrittling of the product occurs when welding with malleable, or with soft iron also, being characteristic of the effect of reheating of the original material.

Some process of welding must be adopted which does not involve the heating of the casting to be repaired to a temperature above the critical point. This critical point is at about 1,350° F.

In Figure 7 is shown a piece of malleable iron welded with Tobin bronze. The melting point of this bronze is so little above the critical point that it is quite possible to melt it in the torch without unduly heating the casting being repaired. It will be seen

in the photograph that little or no change of structure has taken place in the casting being welded. Unfortunately the bronze is not as strong as malleable iron, nor does it adhere as perfectly to the iron as would be the case with welds made of some other iron material. However, for the purpose of making repairs where great strength is not required, this is an entirely feasible method of procedure.

It will be seen that all means of welding with iron so far described have been shown to be failures, largely because they undid what the manufacturer had done to the malleable iron in his annealing process. The conclusion is that if repairs could be made before the casting is annealed these difficulties would not be encountered. The microphotograph reproduced in Figure 8 shows a portion of a weld made in a hard iron casting, using hard iron as the welding material, and then annealing the casting as usual.

It proved impossible in this weld to locate the exact boundary between the original casting and the material welded, although the photograph was taken from an area as nearly as practicable where the two materials joined. It will be seen that this weld differs from normal malleable iron, only in the finer grain. This is an advantage rather than a disadvantage, and welds made by this method will develop the original strength of the material if the skill of the welder is sufficient to avoid any blows or cracks during the process of welding. Unfortunately, however, this character of welding can be applied only in the malleable foundry, for example to reclaim castings it would otherwise scrap on account of blow holes or similar surface defects. It cannot be applied to the repairing of articles failing in service, since of course these articles have been previously annealed.

It is quite possible to weld broken or defective malleable iron articles using white cast iron as a filler, and then re-anneal the casting in order to completely malleableize the latter and to destroy the combined carbon set up in the former due to the re-heating while welding. Figure 8 is a photograph of a weld made in this manner.

It will be seen that this latter method offers a solution of the difficulties encountered in welding malleable iron, provided the welder is equipped with facilities for heat treating the welded article in the same way as they were heat treated by the original manufacturer.

This heat treatment, involving as it does the maintenance of a carefully controlled and fairly high temperature for a considerable time and then the slow decrease in this temperature at a predetermined rate, may present difficulties to the inexperienced operator. It could hardly be attempted except in a heat treating furnace equipped with pyrometers, and would also require expert supervision. Properly executed the excellence of the weld under these conditions is limited only by the skill of the operator. Improperly executed the welded article may be totally ruined and be a source of extreme danger if used in some place where failure would mean serious loss or injury.

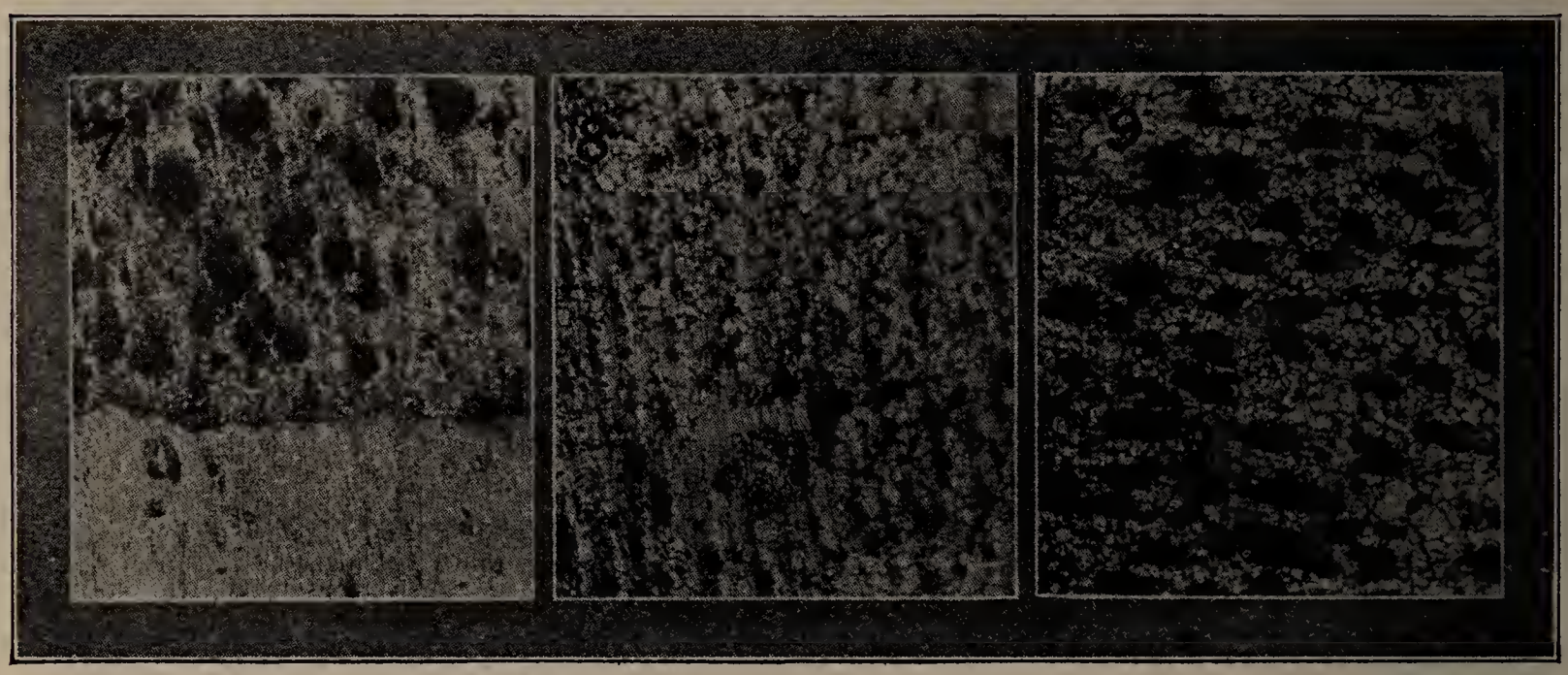
The welds discussed in this article were all made with oxy-acetylene. What has been said of course would, however, apply with equal force to welds made in the electric arc. Thermit welding is not likely to be of service in the repairing of malleable castings, due to their relatively small size, and also due to the fact that the molten steel of the Thermit reaction would not be as suitable a welding material as is the white cast iron filler which can, and should be employed in arc or acetylene welding.

Malleable iron welded with soft iron would not respond properly to the graphitizing heat treatment since this treatment would not convert the combined carbon in the weld itself into body of the casting.

The company with which the writer is connected has made tests on a fairly considerable number of welds made under different circumstances. The result of these tests indicating first, that the serviceableness of a weld is primarily dependent upon the skill of the operator in producing a perfectly sound material and in avoiding the formation of mechanical defects in the weld itself. The matter of skill is of much greater consequence than the details of operation or the materials used.

Preheating to a dull red, or even lower temperature than this is apparently a decided advantage as favoring the production of good sound work. Hard iron proves to be much more desirable welding material than steel. This may in part be due to the fact that it is more fusible and in part also to the fact that it is less easily subject to oxidization while exposed to the welding flame. There seems to be little or no difference in the quality of the welds, whether made in hard iron, or in malleable iron, and this is largely a matter to be considered by individual choice. It is of course to be understood that all of the tests made to serve as a basis for this series of experiments involved the annealing of welded article subsequent to the welding operation.

To secure soundness of weld, the best practice appears to be to use the oxyacetylene flame, to preheat the castings and to use hard iron filler rod. Even with all these precautions, and with a carefully controlled



heat treatment after welding it was still practically impossible to develop the full strength of the material in the weld. This is probably due primarily to the presence of the mechanical defects previously referred to. Articles brazed with Tobin bronze generally fail by a separation of the bronze from the iron, indicating insufficient adhesion of the two metals to each other.

Nearly all the welds made for experimental purposes and discussed above failed through the weld. Such failures are of course only capable of explanation on the theory that the metal constituting the weld is subject to internal flaws.

The writer's conclusion is that the welding of malleable iron parts should not be attempted where the failure of the weld would produce serious accident, but that the reclaiming and repairing of malleable parts suffering from defects not directly affecting the strength is quite feasible, provided suitable annealing is carried out after the completion of the welding operation.

As the welder's art develops, doubtless it will be possible to somewhat extend the field within which it may be good practice to attempt the repairing of malleable castings.

Either now, or in the future, this process should not be attempted by those not conversant with the principles involved and equipped with all suitable means of properly executing the operations.

"Magnolia"

Trade name for welding and cutting equipment, accessories, supplies, etc. Made by Magnolia Gas Products Co., Houston, Texas.

"Mahrvel"

Trade name for oil burning preheating Torches. Made by Mahr Mfg. Co., Minneapolis, Minn.

Malleability

Property possessed by metals which allows them to be hammered into sheets.

Manganese

A metallic element. Added to steel it forms a hard alloy. A small addition of manganese has slight effect but as the manganese content rises above 2.5% the strength and ductility diminish, while the hardness increases.

Manganese Steel, Welding

The welding of manganese steel is a problem which is usually found in the Frog Shop on railroads, although dredge dippers, safes and other machine parts are manufactured from this metal. Some authorities claim that it is possible to weld manganese steel successfully, but in the author's opinion the process is not yet a complete success, by the oxy-acetylene process.

Manganese frogs and crossings contain between 11% and 13% manganese, and the nature of the problem will be better understood when it is explained that when the manganese content is increased above 2% or 3% the strength and ductility decreases, while the hardness increases.

Manganese frogs and crossings frequently require building up at low points. These low spots are usually caused by the metal becoming fatigued and sagging from the constant pounding of rolling equipment. When made frogs or crossings occasionally contain blow holes, or pockets, not visible to the eye. These pockets are generally just below the low point and extend the full length of the section which requires building up. Frogs and crossings containing such defects are not susceptible to a welding process. Should the section require the building up of a worn spot, caused only by constant pounding, it may be treated autogenously.

The frog or crossing should be preheated to about 1250 F. (Medium Cherry) and after the worn spots are built up, during which process the frog or crossing is kept at the aforementioned temperature, it is allowed to cool very slowly. This can be accomplished by burying the object in dry sand.

The parts to be built up should, prior to starting the building up operation, be thoroughly cleaned. Either files, wire brushes, or a portable grinder may be used for this purpose.

The low sections should be built up in sections of about 1 square inch each. Care should be taken to raise the built-up section to the proper height. While the metal of each section is still hot the section should be hammered. This not only expands the new metal, but also serves to impart a finished appearance to the weld. The proper surface alignment may be maintained by the use of a straight edge.

Another method which has been used with success is to immerse the frog or crossing in a pan of sufficient depth and width to permit surrounding the entire object with water, a space of but about ¾ of an inch below the surface of the rail showing. This pan may be so constructed that a constant flow of cold water passes through it. When this method is used no after treatment is necessary.

The correct filler rod to use for this work is manganese, and these rods may be made by cutting up old manganese rails. Manganese welding rods are now manufactured for the welding trade. As manganese possesses a marked affinity for oxygen, however, and will burn out very rapidly under the influence of the torch, the necessary rods should not be cut out from old rails with the cutting torch. Some other method should be used, or preferably, new rods procured. The process of building up the worn section will in itself burn out manganese from both the original rail section to as near a 11-13 per cent content as possible, it is advisable not to multiply the difficulties by an advance reduction of the manganese content in the filler rod.

The author has heard welders complain that under the action of the torch, manganese steel would "foam," making it exceedingly difficult of execute welds. As a proposed remedy for this difficulty it has been proposed that a very fine aluminum wire be wound around the manganese welding rod in the form of long spirals. The introduction of a very small quantity of aluminum into the weld is said to "quiet" the metal. So-called foaming, however, is an indication that the manganese content has been reduced to a very small percentage.

Metallic Arc Welding of Manganese Steel*

So far as known, the commercial arc welding of manganese steel up to the present time, was accomplished only by the metallic arc process with coated manganese electrode material and by water toughening the added metal, the metallic arc form of autogenous welding being particularly adapted to the welding of metal of this character, since it is about the only form of autogenous welding which permits, without difficulty, the water toughening treatment of the added metal.

The normal water toughening treatment amounts to raising the temperature of the metal until the desired structure is produced, and fixing it at that point by an increase of the normal cooling rate. Likewise, in the case of welding manganese, the metal heated to a high temperature by the welding operation, is suddenly cooled from a temperature as near equal to that for the desired structure as is possible.

Electrode Material

The use of a protective coating of the proper character on the electrode material, is necessary to prevent vaporization of the manganese and carbon constituents due to combustion, supported by the oxygen of the atmosphere. The function of the coating

**From a paper read before American Welding Society, by H. R. Pennington.*

is to envelop the metal in fusion with a thin slag film, confine the arc gases and exclude to a great extent, the atmospheric gases.

The coated manganese steel electrode material is furnished in the following standard sizes:

Diameter	Length
1/8-inch drawn	14 inches
5/32-inch drawn	14 inches
3/16-inch rolled	14 inches
1/4-inch rolled	14 inches

The size most generally used for track work is 3/16-inch and 1/4-inch. The 3/16-inch size seems better adapted for general work, especially where 200 ampere welding units are used.

The approximate arc current and voltage values for manganese electrode material are as follows:

Diameter Electrode	Approx. Current Arc	Approx. Voltage Arc
1/8-inch	100-120	20-25
5/32-inch	150-170	22-28
3/16-inch	175-200	25-30
1/4-inch	225-275	25-30

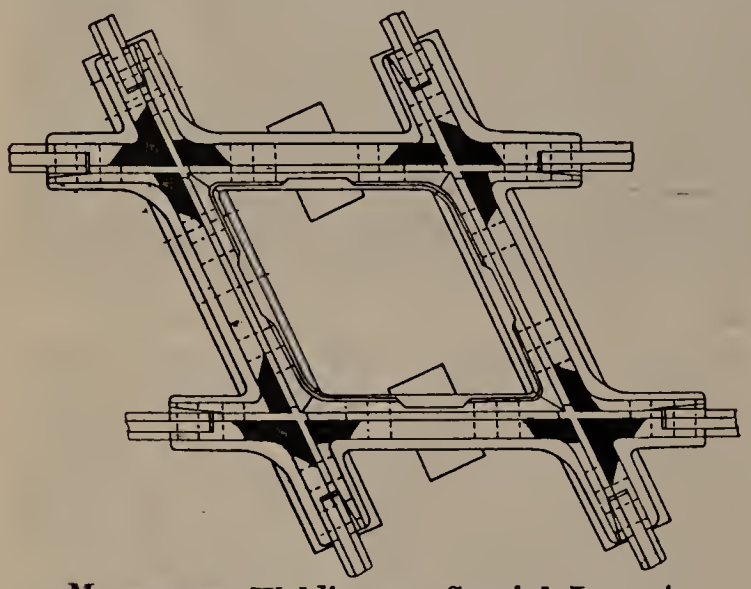
The arc length should be maintained as short as consistent for a uniform flow of metal about 1/8 inch. If with this arc length the metal does not flow smoothly, it is likely that the arc current value is too low.

Polarity

In practice it is found that an electrode-positive polarity gives a better welding characteristic and that the loss of carbon and manganese is less. For this reason where direct current is used, the electrode is made the positive and the work piece the negative.

Arc Manipulation

When welding with manganese steel on either manganese or high carbon steel, it is found advisable to form a rather wide deposit by a slight oscillation of the electrode, to give a deposit approximately double the width of that obtained by drawing the electrode along a straight line. By this manipulation the deposited metal is kept in a molten condition for a slightly longer period,



Manganese Welding on Special Layout.

allowing time for the escape of any gas which may be included in the deposit, and thus preventing the formation of blow holes.

Water Toughening

To prevent the formation of a brittle structure, the work piece including the weld area is kept cool by quenching with cold water immediately after each electrode is used and more often on light sections where the part tends to become too hot, or at any time the welding is interrupted. The result to be accomplished is to keep the work piece cool enough to exercise constantly a quenching action on the deposited metal. Unless the cooling by water is frequent, the rate of cooling will be variable with a corresponding difference in physical character of the added metal.

In track work the cooling is accomplished by directing a small stream of water directly on the previously deposited metal until the heat retained in the part will just dry or vaporize the water. Before the welding is again continued, the surface where the arc is to be established must be dry, otherwise difficulty will be experienced in establishing the arc. It is desirable to wipe the surface

Electric Welded Conveyor Bucket Lip.

dry with a piece of waste when necessary before starting the arc.

In many plants it is common practice to hammer manganese steel welds while they are red hot. According to Mr. L. W. Jones this is by far the best method, as it removes all blow holes, and prevents checking and cracking, which is apt to occur on account of the high contraction of manganese steel from hot to cold.

Welding Procedure

When building up track parts, such as frogs and crossings, it is advisable to apply each deposit diagonally to the direction of the traffic, and terminate the weld on a bias, the point of the bias being on the flange side of the rail, as shown by the accompanying sketch. This procedure is thought to be the best practice in order to minimize the effect of construction and possible structural disturbance on the parent metal from the heat of the welding operation.

To avoid roughness or overrunning of the added metal at the flange side of the rail and on both sides of points, a piece of fire brick or carbon block should be set in the flange groove so as to project up and form a wall for the added metal to flow against. The use of fire brick or carbon blocks for making forms at the extreme points and edges will greatly facilitate the welding and result in better and more uniform work.

Where welding is done out in the open, a small shield 8 or 10 inches high should be set up to shield the arc from the eyes of observers and from air drafts, especially on windy days. Unless the arc is protected from air drafts, welding will be very difficult and an unnecessary loss of carbon and manganese will result.

Finishing

If desired, the weld may be finished by grinding to allow a smooth approach for the wheel and prevent impact at the junction of the weld. However, if pains are taken by the operator to make as smooth a weld as possible, grinding is not considered absolutely necessary. The natural flowing characteristic of manganese steel will in a short time result in the weld becoming quite smooth. The operator should not only endeavor to make a smooth weld but should also use care to see that the top of the weld is level with other parts of the track work, being particular to avoid sharp humps or low spots.

"Manganeseweld"

Trade name for bare and coated high manganese electrodes. Made by Steel Sales Corporation, 129 S. Jefferson St., Chicago, Ill. See Table of Contents, Catalog Section.

"Manganox"

Trade name for high manganese steel rod for acetylene or electric welding. Made by

Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

Manifold

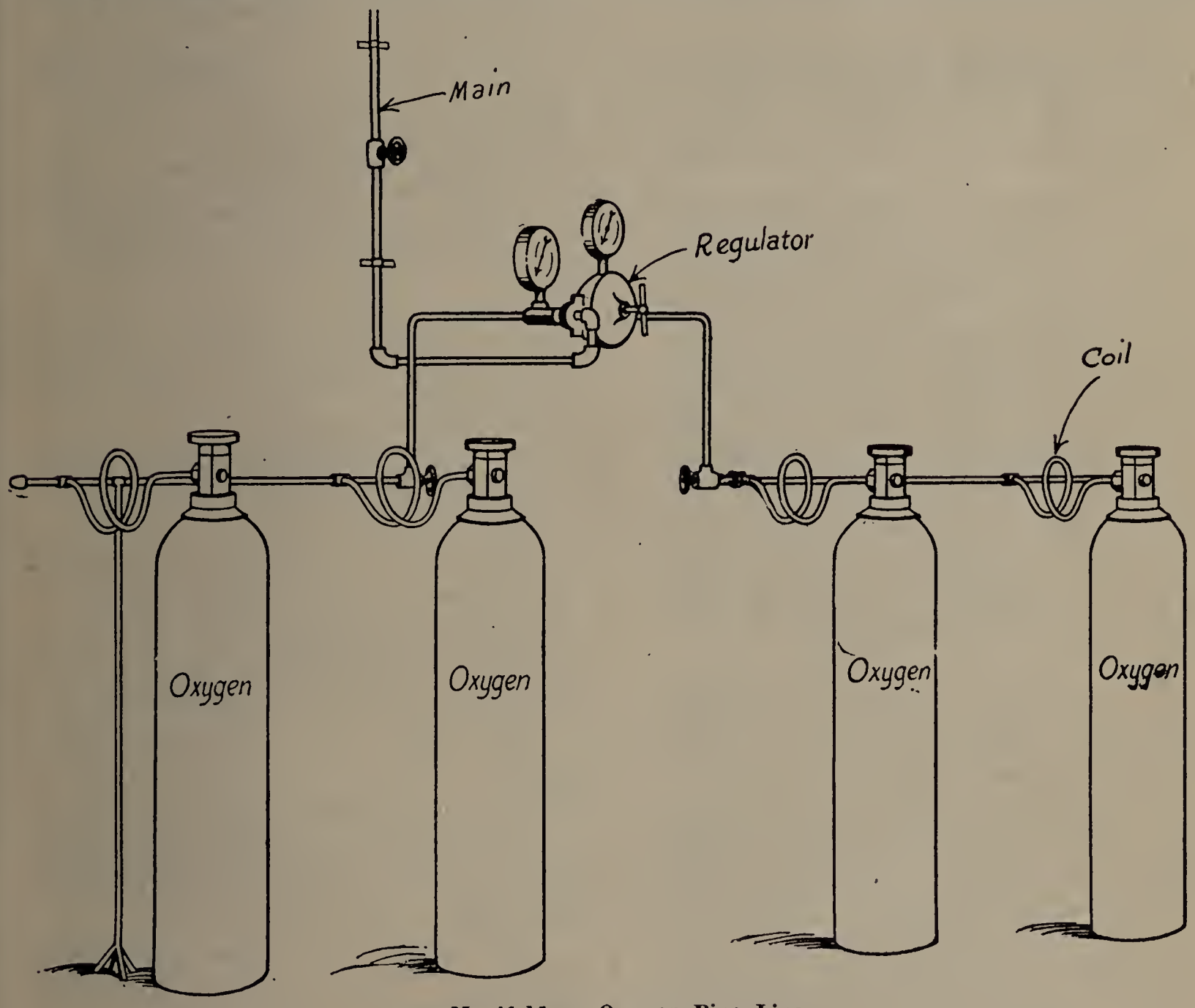
A pipe or header provided with nipple connections and employed to unite cylinders and a pipe line. Manifolds are usually used where acetylene and oxygen is piped to the welding stations, the gas coming from several cylinders. Used in connection with pressure reducers the gas pressure is stepped down before it is admitted to the mains. In some plants it is the practice to install a pressure regulator on each acetylene cylinder to control the gas flowing to the manifold, thus regulating the gas discharge from cylinders under varying pressure. Separate regulators are necessary, otherwise the cylinder containing the greater amount of gas would discharge abnormally fast, while the cylinder containing the lesser amount of gas would not discharge until the pressure in the two tanks balanced.

The use of separate pressure regulators, however, may be avoided by connecting to the manifold only cylinders containing equal pressure. When this practice is followed all of the cylinders connected to the manifold are changed simultaneously. All cylinders should operate under the same conditions so far as temperature, etc., are concerned.

Flexible coil pipes should be provided for the connections between the manifold and the cylinders. In the case of an oxygen manifold, for instance, the manifold should be sufficiently strong to withstand at least 2,000 pounds pressure to the square inch. A ½ inch bore through the manifold should be ample to carry the flow of gas from four to six cylinders. Bronze castings are excellent for the purpose, but they should be free from blow holes or porous spots. In order that cylinders may be changed one at a time, without interrupting the flow of gas, stop valves may be used. When stop valves are used, however, great care must be used to see that valves are not left closed, thereby drawing all the gas in the line from one cylinder. This is more serious in the case of acetylene than it is in the case of oxygen. For an acetylene line it is better to provide two manifolds, stop valves not being used. A battery of cylinders is kept in reserve and when needed are put in service. See "Pipe Lines."

Manifold Lug

When the lug of an exhaust manifold is broken off, a 45 degree bevel should be made on each side of the break and the parts lined up on a perfectly plane surface with the edges at the bottom of the bevel very slightly separated, clamping the manifold and the broken piece in position to make sure that they are lined up perfectly straight. Make a couple of small tacks without the use of filler rod, then remove the clamps and start welding as usual, using the welding flame to get the metal in the vicinity of the weld fairly hot before starting to make the weld. In making the weld, apply the torch so that the greater part of the heat is directed to the heavier section. Test with a straight edge for alignment after the weld is cool.



Manifold on Oxygen Pipe Line.

"Mankote"

Trade name for flux coated high manganese rod for electric welding of manganese frogs, etc. Made by Central Steel & Wire Co., 127

N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Marine"
Trade name for Bronze welding rods. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Marvel"
Trade name for welding fluxes and bronze filler rods. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

Mash Welding
See under "Spot Welding" in chapter on "Electric Resistance Welding."

"Matchless"
Trade name for aluminum flux. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, "Catalog Section."

M. C. B.
Master Car Builders. A section of the American Railroad Association. Their regulations regarding autogenous welding are to be found in the chapter on Rules and Regulations.

Mechanically Operated Welding and Cutting Torches
The efficiency of the hand cutting torches and the evident desirable applications of the principle of metal burning as a machine process naturally led to the development of mechanically operated cutting torches of which the "Oxygraph," "Radiagraph," "Pyrograph" and "Camograph" are examples. A basic principle of these machines is the use of electric motors that provide steady feed motion of rates adjustable to the thickness of the metal being cut. Furthermore, the opening of the oxygen cutting jet valve operates the motor switch and starts the feed motion. With these machines it is feasible to cut to straight and curved lines and combinations in wrought iron or steel of all thicknesses from ¼ inch to 24 inches or more. The limit of heavy cutting with mechanically operated torches has not yet been discovered. See "Oxygraph," "Radiagraph," "Pyrograph," "Camograph" and "Duograph" and "Gewe," in the discussion under "Cutting."

"Meco"
Trade name for welding and cutting apparatus and supplies, accessories, preheating torches, acetylene generators, etc. Made by Modern Engineering Co., St. Louis, Mo.

Melting Points of Metals
The melting points of commercial metals vary, due to slight impurities and therefore be considered approximate only. The data given here is accepted by the United States Bureau of Standards as being the most carefully determined and most probably correct. Melting points above 2000 F. are not known to within 5 or 10 degrees. Impure metals usually have a lower melting point than pure metals. The melting point of alloys cannot always be directly inferred from the melting points of component elements.

Metal or Composition	Melting Point Deg. F	Structure
Aluminum	1200	M
Antimony	1150	B
Brass: 80 C., 202	1700 to 1850	M
70 C., 302		
60 C., 402		
50 C., 502		
Bronze	1675	B
Cobalt	2700	M
Copper	1940	M
Gold	1930	M
Iron—Cast	2300	B
Iron—Wrought	2900	M
Lead	620	S
Manganese	2200	B
Monell Metal	2480	M
Nickel	2600	M
Platinum	3200	M
Silver	1740	M
Steel	2500	M
Tungsten	5400	B
Vanadium	3200	M
Zinc—Cast		
Zinc—Rolled	785	B M

B—Brittle. M—Malleable. S—Soft.

"Mephisto"
Trade name for A. C. arc welding and cutting machines. Made by The Arcwell Corporation, 42 Broadway, N. Y.

Mercury (H_g)
Quicksilver.

"Messer"
Trade name for welding and cutting torches, regulators, etc. Made by Messer Welding Supply Corporation, Brooklyn, N. Y.

"Messer"
Trade name for air liquefaction oxygen plants. Sold by M. Keith Dunham, 110 S. Dearborn St., Chicago, Ill. See Table of Contents, Catalog Section.

Messerschmitt Process
A method of producing hydrogen. It is developed from the principle that if steam is passed over red-hot iron it is decomposed into hydrogen and oxygen. The oxygen in the steam unites with the iron, forming iron oxide, and the hydrogen is set free.

Metal
Any of the metallic elements, either of very high purity or of ordinary commercial grades. Brass or other alloy is a metal in the commercial sense, but an alloy in the scientific sense.

Metal Electrode or Pencil
Usually a metallic wire which is fused by the heat of an arc formed between its end and the part or parts being welded, thereby forming the weld metal.

"Metalcast"
Trade name for aluminum welding rods and flux. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Metal Electrode Holder
Holder for gripping wire electrodes of $\frac{5}{32}$" diameter to ¼" diameter. See "Electrode Holder," and chapter on "Arc Welding."

"Metal King"
Trade name for welding and cutting torches. Made by Straub Mfg. Co., Oakland. Calif.

Metallic Arc Welding
The application of the heat of the electric arc so as to directly melt a metal electrode into a fused bowl on the work at the other end of the arc. See chapter, "Arc Welding"; also "Slavianoff Process."

"Metweld"
Trade name for welding and cutting torches, accessories, supplies and acetylene generators. Made by Metals Welding Plant, 4400 Perkins Ave., Cleveland, Ohio.

Micrograph
A graphic reproduction of any object magnified more than 10 times. When it is desired to indicate that it is a photographic reproducton, the term "photomicrograph" is employed.

"Midget Ebony"
Trade name for a fabric covered hose. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Midget Garnet"
Trade name for a fabric covered hose. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Milburn"

Trade name for oxy-acetylene welding and cutting torches, accessories, supplies, Milburn Wheel Feed acetylene generators, etc. Made by Alexander Milburn Co., Baltimore, Md.

Mild

A term used to denote the carbon content of steel. Mild steel usually is encountered in tank work.

Mixing Chamber

The chamber of the torch in which the gases are mixed. The mixing chamber might be said to compare with the carburetor on an automobile, but instead of mixing air and gasoline the mixing chamber combines and distributes the combustible gases.

Monel Metal*

Monel Metal is an alloy of nickel and copper, containing about 67 per cent nickel, 28 per cent copper and 5 per cent of other elements. This remaining 5 per cent consists partly of iron and partly of manganese, silicon and carbon introduced in the process of refining.

Monel Metal is produced in such forms as wire rod, rounds, squares, hexagons, flats, sheets and castings. In the rolled form it tests as high as 100,000 lbs. per square inch, while the cast form is not quite as strong, having a tensile strength of 65,000 lbs. per square inch. The melting point of Monel Metal is 1360 deg. C. Its coefficient of expansion is .000014 per one degree Centigrade. It has a very low heat conductivity, being 1/15 that of copper.

Monel Metal, like most common metals can easily be welded by following closely the standard welding practice, but good results cannot be obtained unless a few simple precautions are taken. Different metals, when molten, possess different characteristics, and in order to understand these peculiarities the operator should thoroughly familiarize himself with the composition as well as the physical properties of a metal before starting to weld it for the first time.

Oxy-Acetylene Welding of Monel Metal

As an excess of oxygen or too great an excess of Acetylene is injurious to copper alloys, a neutural or slightly reducing flame should always be used in welding Monel Metal. The size of the flame depends partly on the thickness of the metal and partly on other conditions.

The welding tip should be one or two sizes larger than would be required for welding steel of the same thickness.

Avoid welding in a room where there is a draft as this tends to make the weld brittle. The air should also be excluded as much as possible by keeping the torch flame well spread over the weld.

Use only bright Monel Metal wire as a welding rod.

Except in the case of welding thin sheets, it is most important to avoid the use of any flux. Any alloy containing considerable amounts of nickel or copper will, when melted, absorb large quantities of gases if exposed to the air. These gases are dissolved in the metal when melted, but are given up upon solidification, and the result is a porous, spongy casting. Monel metal will be found to flow with a film of oxide on its surface. This oxide helps to prevent the metal from being exposed to the direct action of the air as well as the intense heat of the flame, and for that reason should never be fluxed off. Occasionally a piece of Monel Metal may be found which is difficult to weld on account of an excessive oxide coating. In a case of this kind a little flux will overcome the difficulty, and the regular Borax Brazing flux has been found to give satisfactory results.

The weld should be completed in one place before starting in another, that is, do not weld along the whole length of the weld at the bottom or any particular place before starting to weld at a higher point. If this plan is not followed the surface at different elevations will cool off and in doing so oxidize before the weld is completed, thereby allowing the metal on being remelted to run the risk of becoming full of blow holes.

It is absolutely essential to build all Monel Metal welds well above the surface. There will be noticed at times particles of dirt of foreign matter in the weld. These should always be floated to the top by melting underneath them so that when the weld is built up any slag which might appear can be ground off, leaving sound metal underneath.

Monel Metal can be welded to almost any common metal or alloy.

The methods for welding our various products differ somewhat, and for that reason we consider it best to describe the method for each form separately.

Rods

Start with perfectly clean metal both as to the welding rod and the edges of the part being welded. Bars ⅛ inch and heavier should be beveled to approximately 90 deg. Place the bars end to end just barely touching each other. Proceed as in welding steel, preheating the ends of the bars to a red heat for a short distance away from the V before fusing. Weld from left to right on bars ⅛ inch and heavier, fusing down the sides and bottom simultaneously and allowing all foreign matter to rise to the surface. The welding rod should first be preheated before being brought into the weld and should be allowed to melt underneath the surface of the molten metal without any agitation. Avoid coming back over the weld by welding continuously from one end of the seam to the other, at the same time building up the metal on the surface of the weld as you go along. Do not concentrate the flame for any length of time on one spot so as not to burn the metal. The bottom of the V should be well fused so as to insure perfect penetration. In double V welding the second side should not be welded unless the whole piece is preheated to a dull red. Blocking is advisable in welding Monel Metal as it makes for increased speed because the welder is not afraid that the metal will get away. Most welders, however, feel that blocking is a reflection upon their skill and this method of welding of course is optional with the operator.

The weld when completed should be allowed to cool slowly. A Monel Metal weld when finished appears very rough on the surface, but this should not be taken as indicative of its soundness.

Since a weld is a casting it cannot be expected that a welded rod will be as strong as an unwelded one. A tensile strength of between 45,000 and 55,000 lbs. per square inch can be obtained in a good Monel Metal weld, which is ample for most purposes. Additional strength may be obtained by hammering the weld while still hot.

Sheets

The same care should be exercised in welding Monel Metal sheets as is necessary when welding sheet of any kind. To weld thin Monel Metal sheets up to 1/16 inch, flange the edges not much over 3/32 inch and place them butt to butt in a jig. Care should be taken that the jig is not clamped too tight, otherwise the weld will crack when contraction sets in. Where a jig is not to be

*By *Michael Dzamba in* The Welding Engineer.

had a flat bar should be placed on each side of the seam so as to absorb the heat and avoid serious distortion. The edges should be tacked every 5 inches along the entire seam. Weld from right to left, holding the torch at a slant of approximately 45 degrees and moving it over and parallel with the seam with the flame directly on it. Fuse the edges of the weld flush with the sheet. Because of its thin section a sheet should be welded as rapidly as possible so as to avoid seriously burning the metal. It has been found in thin Monel Metal sheet welding that rapid welding has been retarded somewhat by the oxide coating on the metal which prevents it from running together freely. For that reason it is advisable to use a flux. The regular borax brazing flux dissolved in a little water and applied along the seam as well as on the welding wire will be found to facilitate the speed of welding and also produce a clean, smooth surface.

Another method for welding thin sheets is to place the sheets together with the edges evenly clamped and welding as above. When the weld is finished the sheets can be opened up like a book and the seam flattened by hammering.

Sheets $\frac{1}{16}$ inch and heavier should be beveled. In order to avoid buckling, or overlapping due to contraction, the sheets when laid out for welding should be separated about $\frac{1}{32}$ inch at the end where the welding begins and about $\frac{3}{8}$ inch per foot at the other end. Weld from left to right much the same as rod welding, making sure to fuse the metal thoroughly to insure good union and penetration. Where the sheets are found to pull together too fast due to contraction, wedging or clamping should be resorted to, forcing the contraction to take place in the weld instead of in the sheet. If sheets after welding are found to be warped or distorted they can easily be straightened out by hammering or rolling as Monel Metal welds will be found very soft and ductile, permitting of such work.

Castings

Welding of Monel Metal castings follows closely the practice of cast iron welding except that no flux is to be used. Although Monel Metal castings are less brittle than cast iron they are nevertheless subject to cracks due to differences in the rate of cooling of the different sections of a casting and this difficulty can only be eliminated by making proper allowance for expansion and contraction.

A Monel Metal casting will not permit of successful welding unless brought slowly and uniformly to a red heat. This can be effectively done with the torch flame in the case of small castings. The crack or break should be beveled and aligned in the usual way. Weld similar to cast iron and when the weld is finished it should be wrapped up in asbestos paper or some other good nonconductor of heat and allowed to cool slowly.

Large castings should be thoroughly preheated in an oven or preheating furnace and kept well covered with asbestos paper to exclude the air and hold the heat in uniform circulation around the casting.

When the proper welding temperature has been reached the casting should not be removed from the furnace but welded in the fire by cutting a hole in the asbestos paper along the break just large enough to permit the torch to work without any hindrance. Use Monel Metal welding rod and proceed similar to cast iron welding. When weld is finished allow it to remain in the furnace well covered to cool slowly, thus avoiding the possibility of setting up contraction stresses.

Soldering

Monel Metal can be soldered as easily as copper. The same fluxes, solders, tools and methods are used. Zinc chloride-hydrochloric acid flux as well as most of the paste fluxes can be used with entire success.

Care should be taken when sheets or wire are to be soldered to be sure that the last annealing operation has been properly performed under thoroughly reducing conditions. If such was not the case, it is possible to have a material that will not solder due to a thin, invisible film of oxide on the surface of the material. The fact that a sheet or wire is bright is no guarantee that it will solder. If difficulty is experienced, it can be overcome by annealing the metal buried in charcoal. The same result will be obtained if the material is pickled in some corrosive agent, such as nitric acid, that will actually remove the oxidized surface. This is not recommended except in unusual instances, as nitric acid in all concentrations is very destructive to Monel Metal. Grinding will also clean the part to be soldered satisfactorily. If trouble is experienced in soldering rods or castings, the fault will probably lie in some carelessness of the operator.

Strength of Soldered Joints

Comparative tests have been made on copper and Monel Metal sheets having soldered joints. The sheets were of the same gauge and were soldered by the same man using a ½ and ½ solder. In all cases the joint was 2 inches wide with a ½-inch lap. The following results were obtained:

Material.	Actual Breaking Strength.	Broke In.
Copper	1,910	Copper
Copper	1,910	Copper
Copper	1,970	Solder
Monel	2,905	Monel
Monel	2,605	Monel
Monel	2,400	Solder

Later tests were made duplicating the above. Heavier gauge sheets were used having a 2-inch joint, ½-inch lap and using a ½ and ½.

Material.	Actual Breaking Strength.	Broke In.
Copper	6,400	Solder
Copper	6,170	Solder
Copper	6,430	Solder
Monel	7,200	Solder
Monel	6,085	Solder
Monel	7,420	Solder

Brazing

Monel Metal can be brazed in the same manner as copper is brazed, using ordinary brazing spelter with borax as a flux. It can also be "silver soldered," using a torch with the same flux.

Arc Welding Monel Metal*

Just as Monel metal must be "deoxidized" before casting into sand molds and ingots so must it be also "deoxidized" in producing satisfactory arc-welds. And the agents which are found to be superior for this purpose are the same as those used in the foundry; viz., magnesium, manganese and silicon, in the order of their importance for this operation.

These agents are best employed in the form of alloys, ground to from 50 to 100 mesh and applied to the welding rod of bare Monel wire as a thin coating. It is obvious that the alloys used for this purpose must be sufficiently brittle and preferably, also, soft, that they can be powdered. The binder is very simply made of denatured alcohol containing ½ lb. to the gallon of shellac. Other similar binders would undoubtedly serve equally well.

The exact composition of this coating powder may vary within moderately wide limits, the essential thing being to introduce into the welded metal about the amounts of manganese and silicon and particularly of manganese which are generally used for

**Written by P. D. Merica and J. G. Schoener for the American Welding Society.*

deoxidation in the foundry. Thus one should introduce from 0.05 to 0.50 per cent of magnesium, from 0.20 to 1.00 per cent silicon and at least 0.20 per cent of manganese; the upper limit of manganese is not important, as an excess is not harmful. An excess of magnesium or silicon, however, will tend to produce dirty or brittle metal respectively.

Coatings can be applied dry simply by making a suspension of the powder in the dilute shellac solution and dipping the wire into it and allowing it to dry. The coating can also be applied by brush, although at greater expense of time and with greater loss of material. This coating adheres well and will not be removed by packing and transportation. It will vary in thickness, but on a $\frac{5}{32}$ inch wire will run about a pound to 600 feet and approximately 2 per cent by weight of the wire.

The alloys to be used in the preparation of the powder may vary widely when consistent only with the condition that all must be powdered and that certain limits noted above as to magnesium and silicon content always be maintained.

Entire success has been noted using ferro-manganese or metallic manganese and one of the silicon-manganese-magnesium alloys produced by the Electro Metallurgical Company and having the following composition as described in their booklet:

	Grade No. 1 Per Cent	Grade No. 2 Per Cent	Grade No. 3 Per Cent
Magnesium	25 to 30	14 to 16	8 to 10
Manganese	20 to 25	27 to 33	45 to 50
Silicon	35 to 40	45 to 50	40 to 45
Carbon	Max. 0.20	Max. 0.20	Max. 0.20

Any of these alloys can be used alone or in conjunction with from 1 to 2 parts of ferro-manganese. Of course other alloys or combinations can be used to give similar results. Manganese-magnesium-silicon alloys No. 1 and No. 2 have been used alone and in conjunction with equal parts of ferro-manganese and there has not been much difference between the results with the different composition.

Ferro-manganese alone of with ¼ of that part of ferro-silicon gives good welds at times, but they are not as consistently sound and ductile as with the simultaneous use of some magnesium. The latter seems to be the essential part of the coating, and although the manganese and silicon aid in deoxidation and in producing proper fluidity of the molten metal—and consequently a good weld surface—they serve perhaps also in large part as a diluting carrier for the magnesium. The latter cannot be ground and is also too reactive to be used in the pure form as it oxidizes before it ever gets into the weld. The manganese and silicon act to protect it until it is absorbed in the molten weld. A nickel-magnesium, nickel-copper-magnesium or nickel-silicon-magnesium alloy of similar type could be used as well for magnesium carriers, as they are also brittle.

Aside from the use of the special deoxidizer described above, arc-welding with Monel metal is not essentially different in detail from that with steel.

With work ¼-inch thick and over, a $\frac{5}{32}$-inch welding wire of Monel, for work from ⅛ to ¼-inch, one of from $\frac{3}{32}$ to ⅛-inch should be used, the best current being 180-200 and 75-125 amperes respectively.

It is best to make the whole weld at one operation and not to build it up in successive layers, as the latter method will likely give cracks and unsoundness. The weld should be well built up above the surface, as there are almost invariably small pinholes just under the surface of the weld, even with best welding practice.

An important variation from usual practice with steel is that of making the welding rod positive instead of the work. When the latter is made positive the metal tends to drop from the electrode and does not flow freely and continuously.

In welding sheet, the usual angle should be left for shrinkage amounting to approximately ⅛-inch per linear foot of weld.

The plate, rod or casting should be well cleaned of all scale by grinding or machining on both sides of the weld edge and it is well to coat these edges, by the use of a brush, with the same deoxidizer as is used on the rod.

"Monterey"

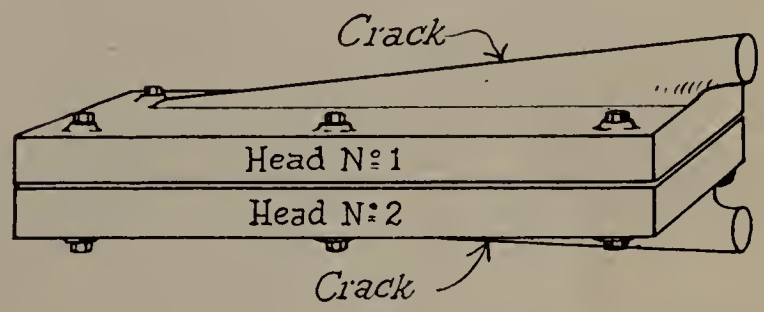
Trade name for hose. Made by Goodyear Tire and Rubber Co., Akron, Ohio.

"Morey"

Trade name for fluxes for all metals. Made by Morey Flux & Chemical Co., Parkesburg, Pa. See Table of Contents, Catalog Section.

Motor Heads

The main difficulty in the welding of motor heads is the complex nature of the casting, which causes shrinkage cracks when the heads are welded without pre-heating, and warpage when a pre-heating fire is used on them. Welders who make a specialty of this sort of work often overcome this difficulty



Welding Motor Heads.

by always heating two of the heads at the same time, bolting them together face to face with six bolts, as shown in the illustration. With the heads bolted together in this manner they can be preheated together and one side welded at a time, then the whole allowed to cool slowly after welding.

Mould Welding

A weld necessitating the use of a mould to retain the molten metal, such as building on a lug, etc. See "Carbon."

Multi-Jet Tip

Common type of tip for oxy-acetylene cutting torch. The oxy-acetylene flame comes from a central hole and the excess oxygen is supplied from additional holes around the central jet.

Multiple Operator Outfit

A generator or motor-generator, designed so that it will supply current for two or more welding circuits at one time. See chapter on "Electric Arc Welding."

Muntz Metal

A term often loosely applied to a brass, i. e., a copper-zinc alloy, that can be mechanically worked while hot. Originally applied to brass of the composition: Copper, 60 per cent; zinc, 40 per cent; such brasses consist of a mixture of two constituents termed "alpha" and "beta."

—N—

"N Brand"
Trade name for wire silver solder. Made by F. H. Noble & Co., 555 W. 59th St., Chicago, Ill.

"Napolitan"
Trade name for a flux for welding sheet aluminum. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"National"
Trade name for electrolytic oxygen. Made by National Oxygen Co., 5811 W. 66th St., Chicago, Ill. See Table of Contents, Catalog Section.

"National"
Trade name for carbide made by the National Carbide Corporation, 342 Madison Ave., New York, N. Y. Air Reduction Sales Co., 342 Madison Ave., New York, N. Y., controls the manufacture and sale of national carbide. See Table of Contents, Catalog Section.

"Natweld"
Trade name for pressure gauges. Made by National Gauge & Equipment Co., La Crosse, Wis.

Needle Valve
A small valve with a conical seat capable of fine adjustment and used in welding and cutting torches to regulate the gas mixture.

Neutral Flame
Well balanced pressure indicating perfect combustion. The cone next to the tip is white hot and beyond it is a long blue streamer. The molten metal is quiet and is clean and flows well. Few sparks are produced. Such a weld will be free from carbonized and oxidized metal. See "Oxidizing Flame," "Carbonizing Flame," and Flame Chart.—

Neutral Flame.

"Newarc"
Trade name for bare and flux coated electrodes, helmets, cables, accessories and electric arc welding supplies. Made by Electric Arc Welding & Cutting Co., Newark, N. J. See Table of Contents, Catalog Section.

Nickel
A metallic element. A small amount of it in steel has the effect of increasing the tensile strength without decreasing the elasticity.

"Nickelweld"
Trade name for chrome nickel steel welding rods. Made by Steel Sales Corporation, Adams and Jefferson Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Nicking
See "Billet Nicking."

"Nickox"
Trade name for nickel steel rod for acetylene or electric welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

Nitride of Iron
An element closely resembling cementite when etched. Caused by the nitrogen of the air uniting with iron at a very high temperature.

Nitrogen
An inert gas present in the atmosphere.

"Noilin"
Trade name for a concentrated compound for lubricating oxygen compressor cylinders. Made by International Oxygen Co., Newark, N. J. See Table of Contents, "Catalog Section."

Non-ferrous
Metals containing no ferrite, or iron. Non-ferrous metals most used commercially are copper, brass, bronze, aluminum, lead and zinc.

"Non-Flash"
Trade name for welding and cutting torches. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Nonox Swedox"
Trade name for steel wire and rods for general acetylene welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

Normalizing
Heating to a sufficiently high temperature to produce a refinement of the grain structure, and holding it at that temperature for ½ hour and cooling in the furnace. The range of temperature for this treatment is between 1,400 and 1,650 degrees F.

"Northex"
Trade name for cast iron welding rods. Made by North Buffalo Hardware Foundry Co., 745 Hertel Ave., Buffalo, N. Y.

"Norton"
Trade name for oil preheating torch, operated by compressed air. Made by Norton Mfg. Co., 18 Tremont St., Boston, Mass.

Norway Iron
A soft, desirable rod for welders. Some authorities hold, however, that American made rods of iron are fully as good as imported rods.

"Norweld"
Trade name for Norway iron, welding rod for acetylene welding. Made by Steel Sales Corporation, Adams and Jefferson Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"No-Ultra"
Trade name for welders' goggles. Made by Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. See Table of Contents, Catalog Section.

"Noviweld"
Trade name for glass for welding goggles. Made by F. A. Hardy & Co., 10 S. Wabash Ave., Chicago, Ill.

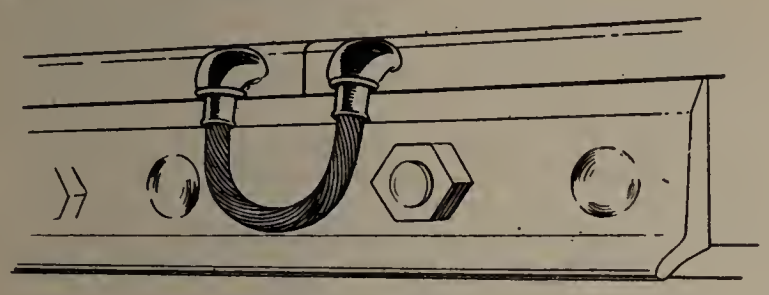
Nozzle
The discharge part of a torch. Sometimes applied to the tip.

"Nuflex"
Trade name for an aluminum welding rod containing its own flux. Made by The Rohde Laboratory, 17 Madison Ave., New York, N. Y.

—O—

"O-B" Signal Bonds

An improved copper cable bond, fitted with pressed steel terminals, the terminals being welded to the outside of the ball of the rail, as illustrated. This bond is designed to re-



Signal Bond.

place the old style wire bonds which will be noticed on track where block-signals are in service. This bond was designed and is manufactured by The Ohio Brass Company, Mansfield, Ohio.

"Oakley"

Trade name for welders' goggles. Made by Chicago Eye Shield Co., 2300 Warren Ave., Chicago, Ill. See Table of Contents, Catalog Section.

Overhead Position

See "Position of Weld."

Overhead Welding With Arc

This usually requires more current for the same conditions, as the arc must be held closer to the work, which means slightly less voltage, so to secure the same heat the current must be raised. See chapter on "Electric Arc Welding."

Overlap

The area of deposited metal which was not fused to the parent metal when deposited.

"Oxace"

Trade name for oxy-acetylene welding torches. Made by Oxace Instrument Co., Schworm Bldg., Massillon, Ohio.

Oxide

A term usually applied to rust, corrosion, coating, film, or scale. Oxygen combines with the metal and such impurities and unless the oxide is removed by the aid of a proper flux the weld will be injured.

Oxidization

See "Oxide." This condition is sometimes brought about by manipulation of the torch flame, or the use of excess oxygen. Iron rust is one form of oxide, and since we are familiar with its ruinous effect, we are assured that the incorporation of oxide in a weld is to be avoided. Water from the oxygen cylinder or wet acetylene, coming through the torch, may be deposited in the weld in the form of water vapors and cause oxidation. The most common cause of oxidation, however, is the improperly or carelessly adjusted flame. This is one of the most common and serious problems for the welder, easy to avoid, but necessitating care at all times.

Oxidizing Flame

Unbalanced combustion caused by excess oxygen. The oxygen combines with all of the acetylene or fuel available and the sur-

Oxidizing Flame.

plus oxygen attacks the metal. The white cone is very short and is surrounded by a blue white envelope. The streamer of the flame is blue. An oxidizing flame causes the metal to spark and a foam or scum forms on the surface of the metal. The weld is shiny and because it contains oxidized metal has little strength. See "Neutral Flame" and "Carbonizing Flame," "Oxide," "Oxidizing," and Flame Chart.

"Oxweld"

Trade name for welding and cutting torches, supplies, accessories, acetylene generators, etc. Made by Oxweld Acetylene Company, Newark, N. J. See Table of Contents, Catalog Section.

Oxygen

Oxygen is a non-metallic chemical element that can be found nearly everywhere in nature, either in free state, or in combination with other elements. It is one of the chief constituents of the atmosphere, and without oxygen, life as we know it, would be impossible. Water is a chemical compound of oxygen and hydrogen, in which approximately 89% by weight is oxygen and one-third oxygen by measure.

Practically all known elements will chemically combine with oxygen under suitable conditions, either directly by the formation of an oxide, or in conjunction with some additional element, forming more or less intricate chemical compounds.

The chemical symbol for oxygen is O. It has an atomic weight of sixteen, and its specific gravity at 32° F. and atmospheric pressure (30 in. mercury) as compared with air is 1.1053. In gas form oxygen is without color, odor, or taste. When liquefied it shows a faint blue color. Under atmospheric pressure the boiling point of oxygen has been established to be—296.5° F. The critical temperature is—180.4° F., and its critical pressure 49.3 atmospheres (725 lbs. per square inch.)

For the welding trade the principal value of oxygen lies in the fact that it will support combustion; in other words, it will combine with other substances, generally with the production of flame and the evolution of heat. This property of the oxygen has been utilized to a great extent in the development of the gas welding torch, as well as in the cutting torch. Regardless of the nature of the combustible gas used in such torches, oxygen is requisite for its operation.

The discovery of oxygen as an element was made by two chemists, Priestly and Scheele, working independently and without knowing of each other's endeavors. Since that time various methods have been perfected for the commercial production of oxygen, of which the following might be mentioned as having practical value today: the chemical method, the electrolytic method, and the liquid air method.

In the first method, a chemical compound, holding an excess of oxygen, is by some chemical reaction forced to give up this oxygen. In the Brinn process, barium dioxide is used; in the Jaubert process a mixture of permanganate of potassium, sodium peroxide and water is used. Both these methods and others of similar nature have gradually been displaced by more efficient methods, as the oxygen obtained is not sufficiently pure for the welding art, and the cost of production is too high, as compared with the electrolytic and liquid air process.

In the electrolytic process a direct electric current is passed through water, to which a small quantity of acid or alkali, such as caustic potash, has been added. The electric current causes a decomposition of the water into its chemical elements, oxygen and hydrogen, the oxygen being liberated and accumulated at the positive pole, and the hydrogen at the negative pole.

The liquid air process is based upon the idea of separating the various gases that constitute the air, by means of a very low temperature, and the consequent liquifying of these gases. Various modifications of this idea have been developed, the principal ones being the processes that carry the names of the following inventors: Linde, Claude, Messer, Heylandt, Pictet, and Hildebrandt. All of them are, however, based on the fact that liquid oxygen has a different boiling point than the other gases present, and consequently, can be separated from them.

The basis of the separation of the elements of air by liquefaction methods was first suggested by Parkinson in 1892 and depends on the difference in the boiling points of the major elements constituting air, these being approximately 297° F. for oxygen and 321° F. for nitrogen.

The problem of separation of liquid air is not very different in principle from the separation or rectification of a mixture of alcohol and water, if it be borne in mind that liquid air separations take place at exceedingly low temperatures. These very low temperatures are reached partly by external refrigeration and partly by taking advantage of the so-called "Joule-Thompson effect"—the fall in tempeature produced when a compressed gas is "throttled" i. e., allowed to expand freely through a nozzle, the resultant self-cooling of the gas being due to absorption of energy (heat) by the internal work consumed in the separation of the molecules of the gas during the expansion. Now when the oxygen and nitrogen are allowed to boil off from the liquid air, the resultant gases are very cold and they are used in all commercial processes to cool more incoming air which it is desired to liquefy; this use of the refrigeration power of the products of the process takes place in a heat interchanger, the principle of which was suggested by Siemens in 1857; without the saving of power made possible by the heat interchanger, none of the liquefaction processes would be commercially practicable.

In 1903 Georges Claude showed that a further cooling effect could be obtained by allowing the compressed gas to expand and at the same time do external recoverable work through the intermediary of an expansion engine. By the application of this principle Georges Claude was able, not only to dispense with outside refrigeration, but to decrease the initial compression necessary.

In all rectification processes, the separation is accomplished by means of the interaction between a descending stream of liquid and an ascending stream of vapor in intimate direct contact with each other. The liquid as it descends becomes richer in the constituent having the higher boiling point, while the vapor as it ascends becomes richer in the constituent having the lower boiling point. - In case the mixture treated in a rectification column is liquid air, the descending liquid stream becomes ultimately almost pure oxygen, while the vapor stream increases its nitrogen percentage as it ascends.

Based upon either one of the above mentioned processes a considerable number of oxygen plants have been established.

Oxygen is supplied to the trade in cylindrical containers constructed in accordance with existing local, state, and federal regulations. A low pressure cylinder in which the oxygen is compressed to about 300 pounds per square inch has been, and still is utilized by some oxygen plants. This type of shipping container is, however, gradually being displaced by the high pressure cylinders, in which the oxygen is compressed to from 1800 to 2300 pounds per square inch. The trade has adopted as its standard sizes, cylinders containing 100, 150, 200, and 250 cubic feet of oxygen when fully charged. A further reduction of these sizes has been contemplated, and the indications are that the 100 and 200 cubic foot sizes will gradually become the accepted standard sizes.

The Interstate Commerce Commission, which, by an act of Congress regulates all interstate shipments of all compressed gases, has issued specifications for the construction of oxygen cylinders, as also regulations for shipments of these cylinders. The low pressure oxygen cylinders must be constructed in accordance with Shipping Container Specification No. 7, now in effect, whereas the high pressure oxygen cylinders must comply with Specification No. 3A. The Bureau of Explosives, No. 30 Vesey Street, New York City, has been given the authority to enforce these Specifications, as well as the rules for transportation of these cylinders, and the Bureau should be consulted for proper information.

In the year 1800, Nicholson and Carlisle showed that on conducting an electric current through water by dipping the two terminals of a voltaic pile into it, at one of the terminals hydrogen and at the other oxygen, was produced. While strictly speaking pure water dissociates into hydrogen and hydroxl ions, for all ordinary purposes the conductance of pure water is negligible, therefore in the commercial electrolysis of water the water is made a conductor by the addition of alkalies or acids. The alkalies are almost entirely used commercially because of their cheaper cost, and the resistance of a greater class of materials to their chemical action.

When an electric current is passed through such an alkaline solution, the water is decomposed by a primary and secondary reaction so that the hydrogen is liberated at the negative pole or cathode, and the oxygen is liberated at the positive pole or the anode. The equipment necessary for the decomposition of water is a suitable container to hold the alkaline or acid solution of water, called the electrolyte; an anode, which is submerged in the solution and to which the current from some outside source is led; a cathode, submerged in the solution to receive the current and lead it back to its source; a dividing wall to separate the gases and means for collecting them separately and conducting them to some desired point

The current necessary must be in one direction quite naturally, in other words, it must be a direct current so that the evolution of gas will be at the same point always. It is possible to use an alternating current, but the use of such a current means the change of a pole from anode to cathode as rapidly as the current alternates in direction. Commercially, no alternating current electrolytic apparatus has been developed and all such equipment is operated by a direct current. This current, in its passage from the anode through the solution to the cathode, decomposes the water.

Commerical electrolytic apparatus now in use in this country and probably in other countries operates at a thermal efficiency varying from perhaps 70% to almost 90% and although the art, from a commercial standpoint is comparatively new, progress and development of apparatus has been reasonably rapid.

The introduction, development and use of hydrogen for the cutting of steel in connection with oxygen and the large demand for hydrogen for the hydrogenation of oils and other industrial purposes is no doubt a further contributing factor in the development of the art.

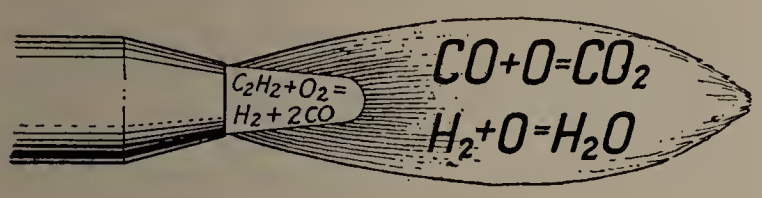
The distinctive features of this method of producing oxygen is the simultaneous production of two volumes of hydrogen for every one volume of oxygen produced.

Units for small plants are connected in series. For larger plants, in series parallel, so that by a multiplication of units practically any size plant can be installed.

Hydrogen and oxygen are used in the autogenous welding process and in the cutting of steel. The oxy-hydrogen flame temperature is approximately 4300 degrees and being lower than the flame temperature of other available combustible gases, its use in the welding process is limited to particular kinds of work.

Oxy-Acetylene Flame

Flame produced by the combustion of a mixture of nearly equal volumes of acetylene and oxygen. This gives the highest



Oxy Acetylene Flame.

flame temperature known, 6300° F., and the easiest flame to regulate. It is the flame most used for welding. See Flame Chart.

Oxy-Benz Flame

A German term applied to a mixture of oxygen and the vapours of benzol, benzine or other liquid hydrocarbons. The combustible liquid must be vaporized, which results in an indifferent regulation of the flame, which is sometimes oxidizing and sometimes carbonizing. The temperature is higher than Oxy-Hydrogen or Oxy-Street Gas, but much lower than Oxy-Acetylene.

Oxy-Coal Gas

A mixture of oxygen and illuminating gas, sometimes referred to as "Street" or "City" gas. This mixture was first used in 1838 by Debassyns de Richemont. An early torch designed to use this mixture commercially was constructed by Claude.

The temperature of an Oxy-Coal Gas flame is lower than Oxy-Hydrogen, another reason why it is not suitable for welding. Some success has been claimed for it, however, for cutting, particularly on the Pacific Coast. See "Street Gas."

Oxygen Cylinder

See "Cylinders"

Oxy-Electrode

An electrode that gives off oxygen at the temperature of the arc.

Oxygen Tank Wrench

A small detachable wrench which fits over the valve of an oxygen cylinder and which enables the welder to open the cylinder readily.

"Oxygraph"

Trade name for mechanically operated oxy-acetylene cutting torch, formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

Oxy-Hydric Torch

A torch using oxygen and hydrogen for cutting. See "Oxy-Hydrogen Cutting."

Oxy-Hydrogen Flame

Flame produced by the combustion of a mixture of one volume of oxygen with two volumes of hydrogen. The proportion should be one to four if the flame is to be used for welding, in order to prevent oxidation of the metal. The temperature of the flame is about 4300° F.

Oxy-Street Gas Flame

Flame produced by the combustion of a mixture of oxygen and street gas. Oxidation is fairly certain to result because the low pressure of the street gas does not allow its being used in sufficient quantity to overcome this effect.

—P—

Padding

Depositing metal by the metallic arc welding process by running beads parallel to each other in such a way that the beads are united with one another to form a solid mass. This is used for building up operations and for filling in large cavities when heavy sectons are being welded. Each bead which is deposited must then be considered as a part of the parent metal and the next bead which is added to it must unite with it thoroughly, just as though it were being laid on the parent metal. More satisfactory results can easily be obtained if the beads are laid parallel to the longest dimension of the weld. If a number of beads will be required, it is well to surround the outer edge of the area of the weld with a ridge of beads. In the chapter on Electric Arc Welding will be found a discussion of the "Welding Departments." In that discussion there are illustrations of four exercises which the operator should study as a preliminary to attempting actual work on the padding weld. It should be noted that in these exercises, spreading is combined with padding. Padding on a vertical surface is preferably started by running a series of beads horizontally across tthe bottom, after which the work may be completed by working down from the top. If padding is done on the surface which works down to a sharp edge, great care must be taken to keep slightly away from the extreme boundary so as to avoid breaking down the thinnest part of the section. The usual cause of poor results lies in running the beads too far apart in an attempt to cover the surface with the smallest possible number of beads. The next most common defect is the failure to clean each layer of deposited metal before adding the next one.

Padding Weld

A succession of overlapping beading or spreading welds, merging so as to result in an even surface. This process is used in building up broken parts, worn parts, etc.

"Page-Armco"

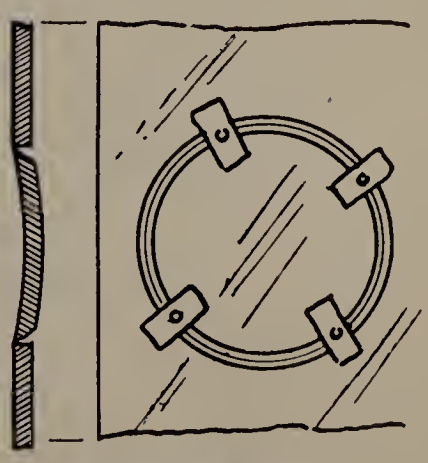
See "Armco."

"Parsons'"

Trade name for manganese bronze welding rods. Made by The Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, Pa. See Table of Contents, Catalog Section.

Patching Sheets

The diagram shows a method of putting in a patch in a plate whether a plane, round or warped surface where much trouble has



Patching Sheets.

been experienced in keeping a welded patch from cracking during the welding or after welding or in service or where from experience such danger is liable. In the cross section, note the patch is slightly dished, the

idea being that the contraction during welding will just about take up the dishing and straighten out the plate that is used as a patch relieving all strains. The ideal patch in this case is a circular one but ofttimes a true circle cannot be arranged for but the nearer a circle is approached the better the chances are for success. For instance, if the hole is rectangular, rounding the edges will help a whole lot and if the hole is odd shaped, making it an ellipse or egg shape will approximate the circle where the stresses are even all around.

Where a machine formed dished patch cannot be obtained an ordinary sheet can be dished by hammering. If the sheet is over ¼" thick it should be hammered hot and it is best hammered hot for any thickness.

The four clamps show an easy method of holding the plate in place, simply putting a bolt through from the inside and clamping down with a heavy plate and nut on the outside. These clamps should be left in place as long as possible in this rigid system of welding. This system not being at all applicable to the non-rigid system, as it is a rigid weld with the stress transferred to the dished patch. See "Boiler Welding."

Pearlite

A mechanical mixture of iron and carbide of iron, or usually described as alternate plates of Cementite and Ferrite. For a short name "Pearlite" has been adopted, as under reflected light it has a luster like mother of pearl. These plates are very thin, usually less than 1-25,000 of an inch. See "Cementite," "Ferrite" and "Cast Iron, Hard Spots In."

"Pearlitic"

Trade name for iron welding rods. Made by Morey Flux & Chemical Co., Parkesburg, Chester Co., Pa. See Table of Contents, Catalog Section.

Peening

Stretching the surface of cold metal by hammering.

"Peerless"

Trade name for aluminum welding rods. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

Penetration

The very essential art of starting complete fusion clear through the welding line or at the bottom of the V. Thorough penetration and absolute fusion is a condition very essential to successful welds. Thorough penetration, however, is not always possible, on thick pieces or pieces more than ⅛ inch thick, unless preceded by beveling. See "Adhesion" and "Beveling."

Figure 1 illustrates the case of lack of penetration commonly found in welds when the edges have been simply brought together without beveling. A thin film of oxide has worked through to the reverse side, giving the deceptive appearance of a weld which has penetrated thoroughly.

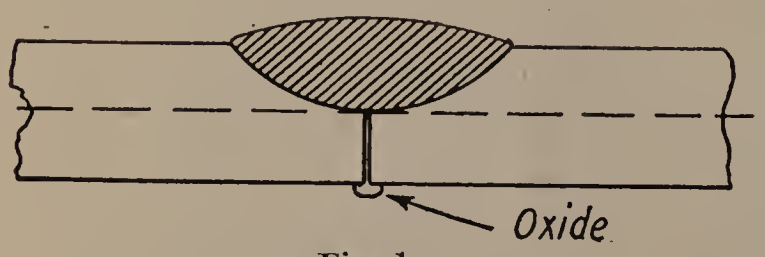


Fig. 1.

Figure 2 illustrates a case where the metal has not been beveled, but the edges have been separated before starting the weld. While thorough penetration has not been secured, it will be noted that some molten metal worked down into the crack at the bottom of the weld and simply adhered to the lower faces of the parts to be joined, without making thorough fusion. The examination of the reverse side of the weld can be deceptive, especially when a clearly defined ridge of metal is not present to prove that the fusion has penetrated.

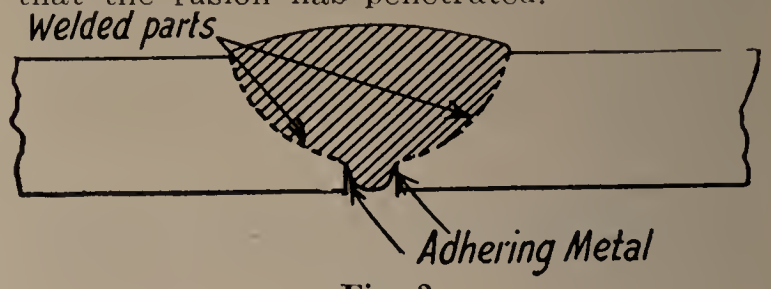


Fig. 2.

Figure 3 shows a very mild case of lack of penetration from three different causes. First, from lack of beveling, second, from changing the levels of the plates, and third, from failing to make the proper separation before welding, so that the contraction of the

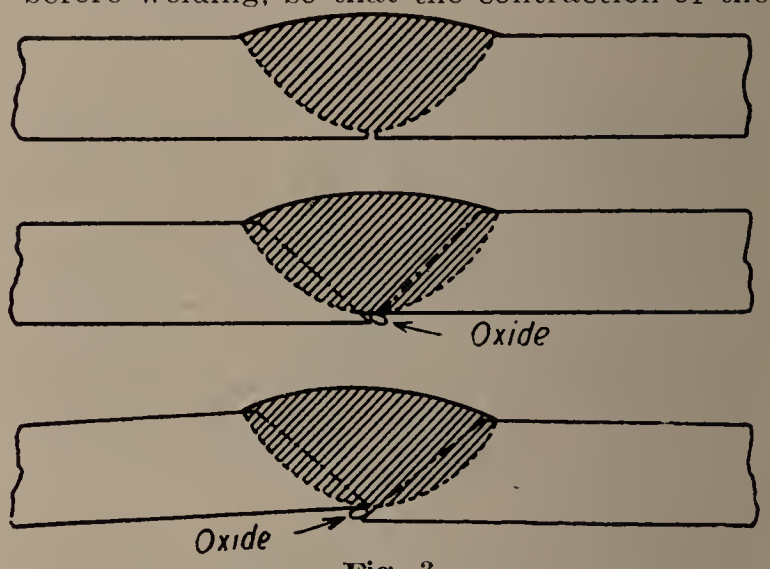


Fig. 3.

puddle pulls one of the edges up over the other. In each one of these three cases there is an incipient crack on the reverse side of the weld which may be the cause of a failure. The only remedy for failures of this kind is constant practice in getting thorough penetration. Penetration should be made evident by successive drops fairly close together. In some cases welders make sure of this penetration by running a light weld on the reverse side, as shown in figure 4. When following this procedure, however, great care must be taken that the second weld penetrates all the way through so as to fuse with the metal which has already been deposited in the first weld. (See under "Wash Weld.")

Fig. 4.

The welder should make a distinction between "heat penetration" and "weld penetration." It is agreed by those who have studied the welding art that there is a difference between the depth to which the base metal is melted and the depth to which the amalgamation of the filler and base metals extend. This latter depth is usually what is spoken of as "penetration."

Percussion Welding

An electric welding process. The parts to be welded are heated instantly by the sudden discharge of a heavy electric current from a condenser, at the very moment when the current is discharged from the condenser the two parts to be welded together are forced together with a rapid blow. The sudden rush of the current momentarily melts the portions of the pieces that are to be joined, and by forcing them together at that moment a good weld is secured. This process has been found to be particularly well adapted to the welding of wire. See chapter on "Electric Resistance Welding."

Phosphorus

Phosphorus is, beyond a doubt, a great enemy of the welder. When burnt, in the form

of phosphuretted hydrogen, it is responsible for a very unpleasant atmosphere in the welding shop. When present in gas it undoubtedly passes almost entirely into the weld. The French Association have conducted some tests by using acetylene containing an abnormal quantity of phosphorus and declare that it was possible to see the metal ball together without uniting. Phosphorus will cause welds to be porous and brittle.

Photomicrograph

A photograph of microscope enlargement of welded test pieces. The welded specimens are sawed, or tested to destruction, and filed, polished and etched, after which photographs on an enlarged scale may be made. See "Etching" and "Testing Welds."

Pickle

To soak metal in acid solution in order to free the surface of the metal from rust or scale, preparatory to electric butt welding. A good solution can be prepared by using one part sulphuric acid (H_2SO_4) and thirty to fifty parts water. The tank used should be lined with lead, stone, or wood, and the solution well heated. Sulphuric acid thus diluted will quickly remove scale, but the parts should immediately afterward be dipped in hot limewater (1 lb. lime to 3 gals. water). The metal will dry quickly and retain a thin coating of lime, which prevents further oxidation. Heating the solution is an economy measure, as the hot acid solution can be more diluted than when cold.

Pintsch Gas

Pintsch Gas is a trade name for a combustible gas produced by the destructive distillation of petroleum or some of its distillates. It is the oldest of the commercially compressed combustible gases, and has had a tremendous influence upon the development of the compressed gas industry. Its use for the lighting of railroad coaches and isolated lighted aids to navigation is well known.

Pintsch gas is a mixture of various gaseous hydro-carbons produced by the heating of oils in retorts to a temperature of from 1100° to 1600° F.

Pintsch gas is recommended by the manufacturers for welding and particularly for cutting. It is supplied to the trade either in low pressure containers charged to 300 pounds per square inch, or in seamless drawn steel cylinders charged to 1800 pounds per square inch. In the latter form it is given the trade name of Isolite, to denote its portability and usefulness in isolated places.

Low pressure Pintsch gas cylinders must comply with Shipping Container Specification No. 7, and high pressure Pintsch Gas Cylinders with No. 3A, as issued by the Interstate Commerce Commission. Regulations for shipment of these cylinders are issued by the same Commission, and enforced by the Bureau of Explosives, No. 30 Vesey Street, New York City.

Pipe Lines (Acetylene-Oxygen)

The size of pipe required for an oxygen pipe line depends upon the number of welding stations and the length of the line. When the length of the line does not exceed 300 feet and the hourly oxygen consumption does not exceed 500 cubic feet a ¾ inch pipe will answer. The extensions to the welding stations should be of ½ inch pipe. The turns should be made of bent pipe, rather than screwed joints, and the joints should be welded. This eliminates the disturbing effect of a sharp right angle turn. A safety device of some sort should be connected to the oxygen line, to guard against over pressure in case of a faulty regulator. A prominent manufacturer of apparatus recommends the use of a thin brass disc, clamped between a flange and a cap. The flange is tapped for screw connection to the pipe line and the cap is perforated with several holes communicating to the atmosphere. The diameter and thickness of the metal disc is such that it bursts under a pressure of say 100 pounds per square inch and relieves the oxygen pressure, thus calling attention to the defective regulator.

The size of pipe required for an acetylene line is somewhat larger than for oxygen. This is because the pressure should never exceed 15 pounds. A one inch pipe is best to serve twenty welding stations.

Copper tubing should never be used. Acetylene in contact with copper forms copper acetylide, a very dangerous substance which may explode and cause fire. Brass should not be used in acetylene line, but may be used for stop valves. Black iron or galvanized pipe with welded or screwed joints may be used.

Stop valves should be used liberally. Place one between the line regulator and the line so that the regulator may be removed. It should also be possible to cut off any welding station when necessary.

Acetylene pipe lines should be protected from back fire by a water seal, and they should be installed at each main line and branch line. The gas bubbles through the water which, however, will stop a back fire. The traps or backfire chambers should be kept full of water.

Never use oil or grease on the threads of a gas line. Use soap or a graphite compound.

When installing pipe lines it would be well to consult a manufacturer of apparatus, experienced in such matters. See "Manifold."

Pipe Welding

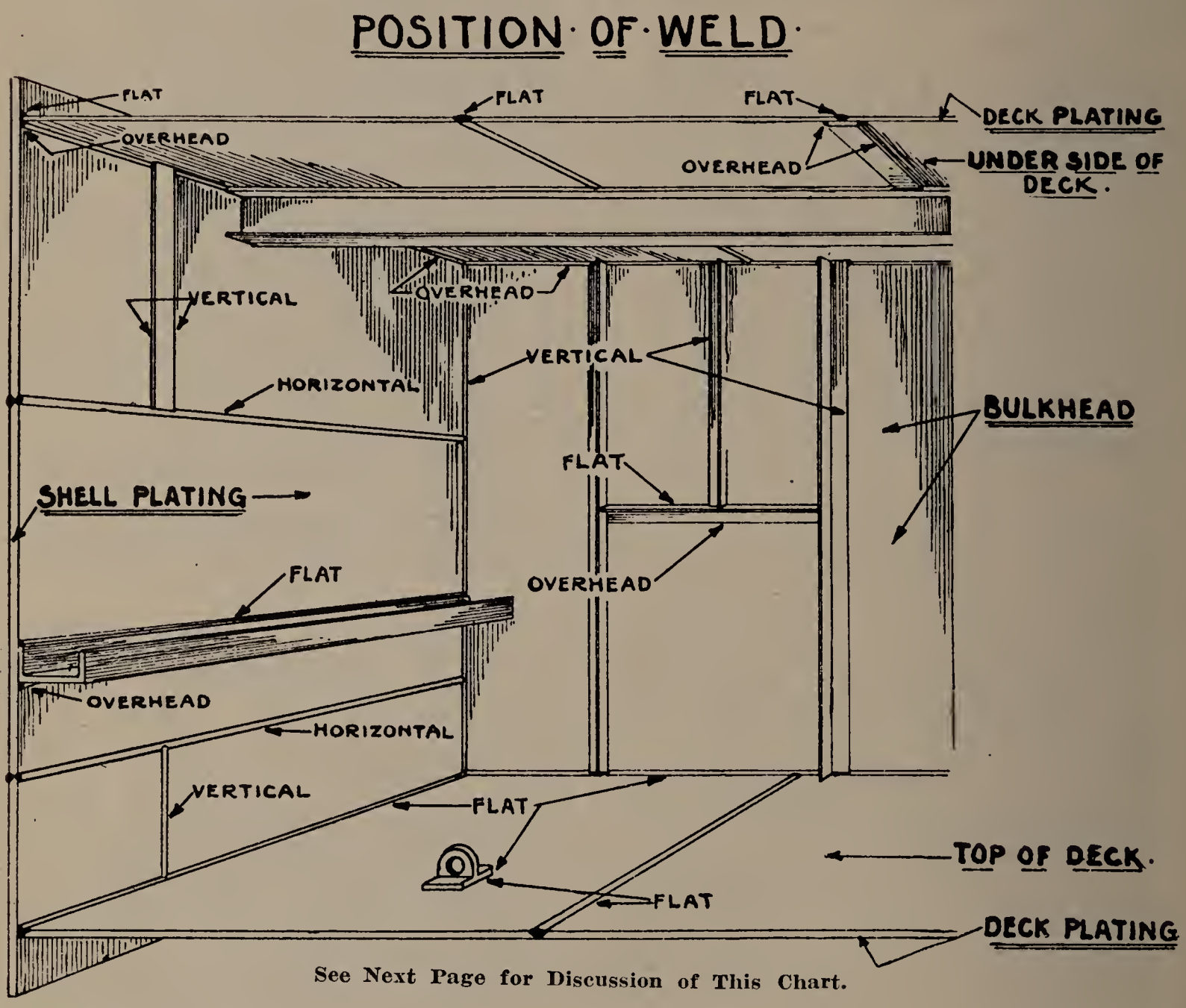
A great many tests and experiments have been made with welded pipe joints of various sizes. The results of these experiments and tests indicate that welded joints are fully equal and possibly superior, to the ordinary coupled (malleable) joint. Early in 1917 a series of tests of welded and screwed pipe connections were made at Fowler Shops, University of Kansas. These tests were very far reaching and exhaustive and proved beyond a doubt that in ordinary pipe line work a competent welder, by exercising the usual care and precaution, could be depended upon to produce a joint which would be practically the same as unwelded pipe. It was found that by slightly reinforcing or over-charging the weld, that the weld was even stronger than the rest of the pipe. The result of these tests conclusively proved that pipe lines which were welded by competent operators, and which were tested before being put into operation, to guard against possible defective welds, were much preferable to pipe lines with screwed connections.

Pipe of all sizes should be butt welded. When possible, pipe should be ordered cut in such a way that the butts will form a 60 degree angle. When this is not possible, the ends must be beveled in a manner most convenient and economical for the welder. So far as the actual welding procedure is concerned, the usual directions for torch manipulation will prevail. Use the rod required for the particular class of pipe to be welded. Make sure you are using a tip large enough to give sufficient penetration to insure fusion at the bottom of the bevel or V. Start the weld at the top of the joint and weld as far to the right as possible, at least half way round. Then start at top and weld to the left to point where first operation ceased. Make sure that you have fusion at top and bottom points, where starting and stopping occurred. When possible, overcharge the weld slightly. Don't be afraid to go to the bottom of V. Forget you are dealing with a hollow pipe. It would be preferable to go thru the V rather than to leave a faulty joint which would develop a leak, possibly after the pipe line was buried.

A welded pipe connection is more durable and lasting than a screwed connection. Oxidation proceeds more slowly in welded joints, because of the fact that there has been no diminishing of the strength of the walls, because of threads. See chapter on "Pipe Welding."

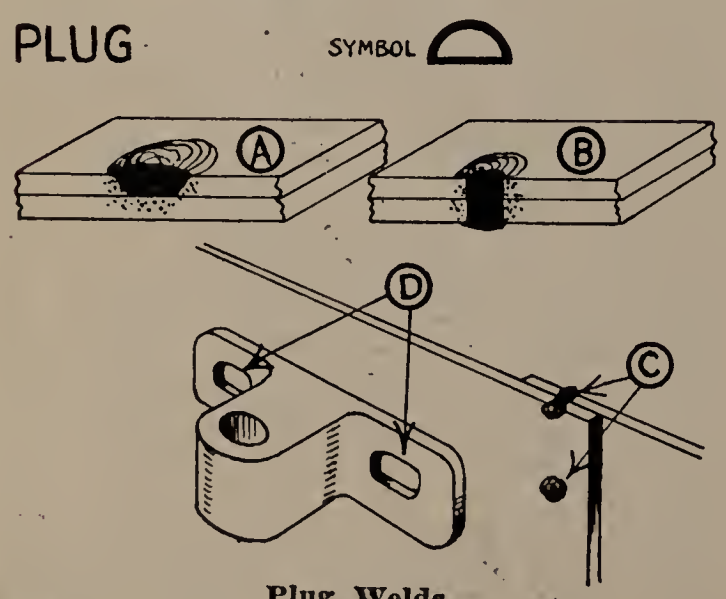
Planimetric Method for Grain Count
See under "Grain Size."

in either one plate ("A") or both plates ("B"). Also used for filling through a bolt hole as at ("C"), or for added strength when fastening fixtures to the face of a plate by drilling a countersunk hole through the fixture ("D") and applying the welding material through this hole, as at ("D"), thereby fastening the fixture to the plate at this point.



See Next Page for Discussion of This Chart.

"Plastic-Arc"
Trade name for electric arc welding machine. Made by the Wilson Welder & Metals Co., Inc., 132 King St., New York. See Table of Contents, "Catalog Section."



Plug Welds.

Plasticity
State of being plastic or easily changed in shape.

Plug Weld
A plug weld (see sketches) is used to connect the metals by welding through a hole

Plumb-bob
A weight with a conical tip suspended with a string, to show the vertical line.

"Pneumercator"
Trade name for gas pressure indicators. Made by Pneumercator Co., Inc., 15 Park Row, New York City.

Point Welding
The joining of metal surfaces by a raised point or projections in which the current is confined or concentrated and the welding takes place only at these points, this process usually being employed in the manufacture of sheet metal. See "Spot Welding" in chapter on "Electric Resistance Welding."

Polarity

It is common knowledge that the positive terminal of a carbon arc is hotter and consumes more energy than the negative terminal. If the graphite electrode of the welding arc is made the positive terminal, energy will be uselessly consumed and the resulting higher temperature will increase the loss of carbon through excessive oxidation and vaporization. Moreover, for reasons well known to those familiar with the phenomena of arc formation, a very unstable arc is obtained with the iron parent metal functioning as the negative electrode. The graphite electrode should therefore always be connected to the negative terminal. reversal of polarity being detected when

the arc is difficult to hold and when the carbon becomes excessively hot.

Pole

One of the two terminals of an electrolytic generator, known as positive and negative poles.

Polymer

The product of high temperature generation in an acetylene generator. This sometimes results from recharging a generator without removing the residuum which collects in the bottom of the reservoir, which reduces the water capacity and may cause over-heating and polymerization. This condition reduces the amount of acetylene generated from the carbide. Polymerization is indicated by the presence of yellow tarry deposits on the residuum.

Pool

The small body of molten metal, or puddle, created by the flame of the torch.

Popping

See "Back-Fire," "Flash Back," etc.

Position of Weld

This chart was prepared by the Welding Committee of the Emergency Fleet Corporation. It illustrates the various positions of welds that may be required in shipbuilding and will be found useful in ordinary welding practice.

Flat position is determined when the welding material is applied to a surface on the same plane as the deck, allowing the electrode to be held in an upright or vertical position. The welding surface may be entirely on a plane with the deck or one side may be vertical to the deck and welded to an adjoining member that is on a plane with the deck.

Horizontal position is determined when the welding material is applied to a seam or opening the plane of which is vertical to the deck, and the line of weld is parallel with the deck, allowing the electrode to be held in an inboard or outboard position.

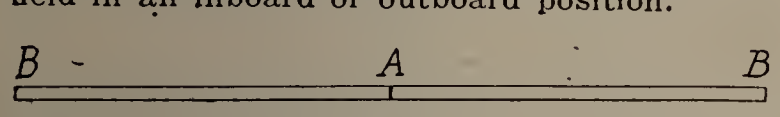


Fig. 1.

Vertical position is determined when the welding material is applied to a surface or seam whose line extends in a direction from one deck to the deck above, regardless of whether the adjoining members are on a single plane or at an angle to each other. In this position of weld the electrode would also be held in a partially horizontal position to the work.

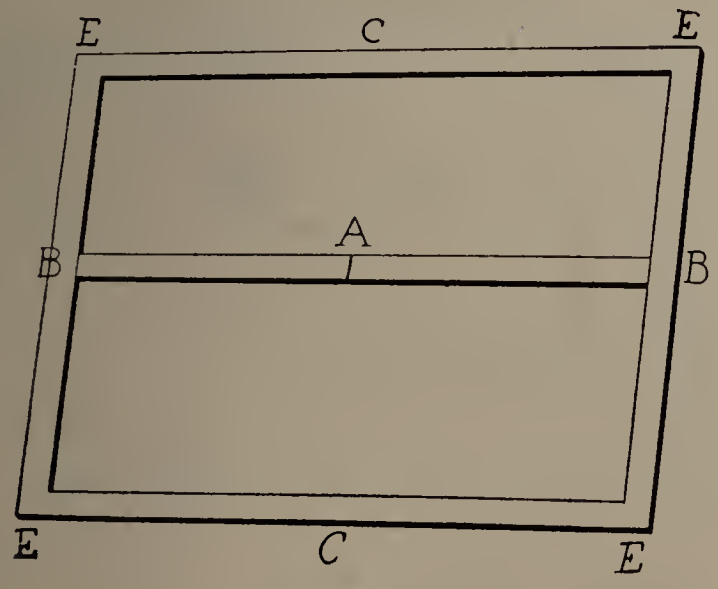


Fig. 2.

Overhead position is determined when the welding material is applied from the under side of any member whose plane is parallel to the deck and necessitates the electrode being held in a downward or inverted position.

Preheating

Preheating parts to be welded is resorted to by the welder for three very important reasons. The first reason is to offset or compensate for internal strains or warpage which may be caused by the welding operation. The second reason is to save acetylene and oxygen, by reason of the fact that the temperature of the object to be welded can be raised more economically by some means other than the flame of the torch. The operators' time is also conserved, for during the preheating period he is free to give his

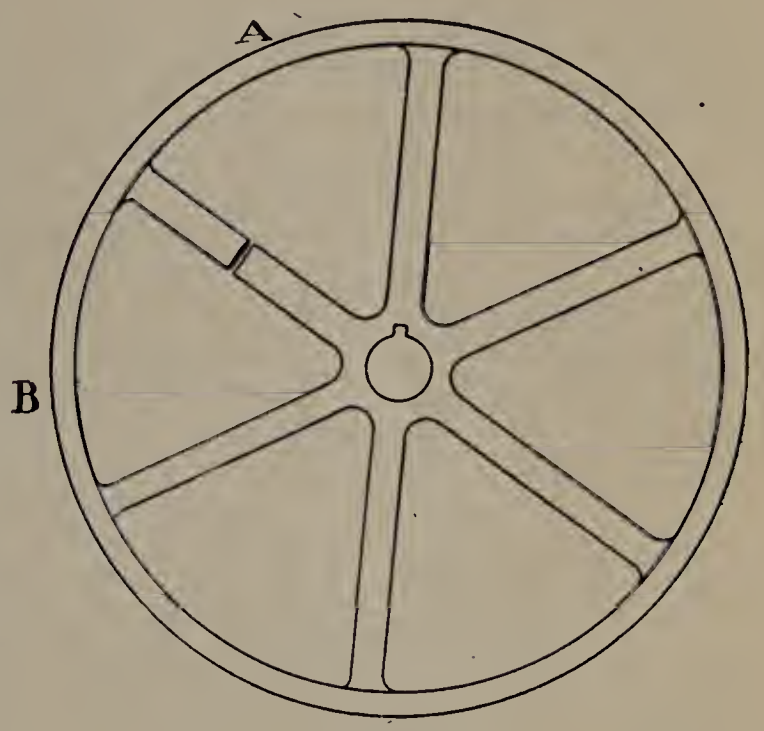


Fig. 3.

attention to other work. The third reason is because preheating, and after heating, too, often improves the quality of the weld. Not only does proper preheating remove strains caused by the welding process, but also quite frequently the process removes or minimizes strains which originally existed in the broken part and which may have been wholly or partially responsible for the break.

There are three agencies used for preheat-

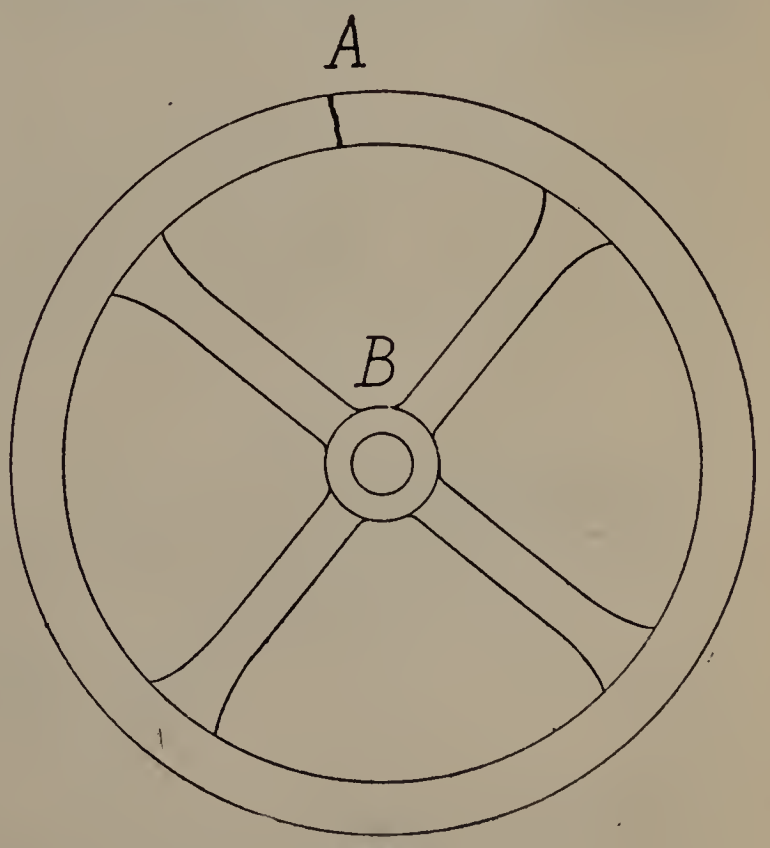


Fig. 4.

ing purposes and they are: city gas, oil and charcoal. Several types of preheating torches are manufactured, some of which for fuel consume city gas, some oil under pressure, and in one instance a preheating oven, or furnace, the fuel for which is city

gas. For some classes of welding, notably fly-wheels, gear-wheels, etc., a concentrated heat is necessary, and for this class of preheating a city-gas or oil burning preheating torch is best. The experienced welder, who has studied expansion and contraction problems, is often able to concentrate heat at certain points, rather than heat the entire object, thus saving time and fuel. For this type of work a preheating torch, using one of the fuels before mentioned, is desirable.

Charcoal, as a preheating agency, is very

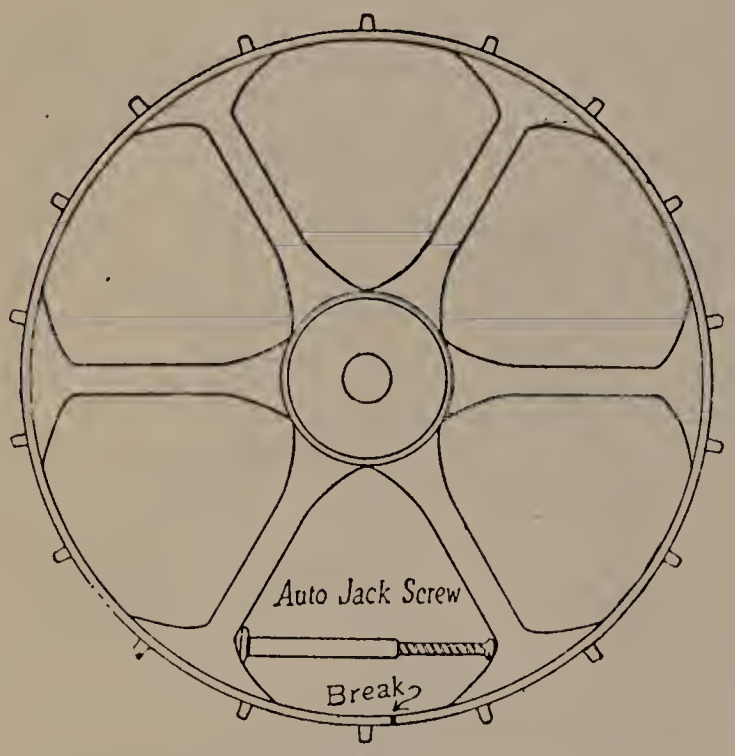


Fig. 5.

satisfactory, for the reason that it burns with a clear, hot flame, it will not injure finished surfaces, it needs no blast to keep it going, and the heat is developed slowly and decreases in the same manner. The combustion of charcoal, however, produces a great deal of carbon monoxide, a poisonous gas, which has an adverse effect on the blood, and a charcoal preheating fire should therefore not be used in a poorly ventilated room or shop.

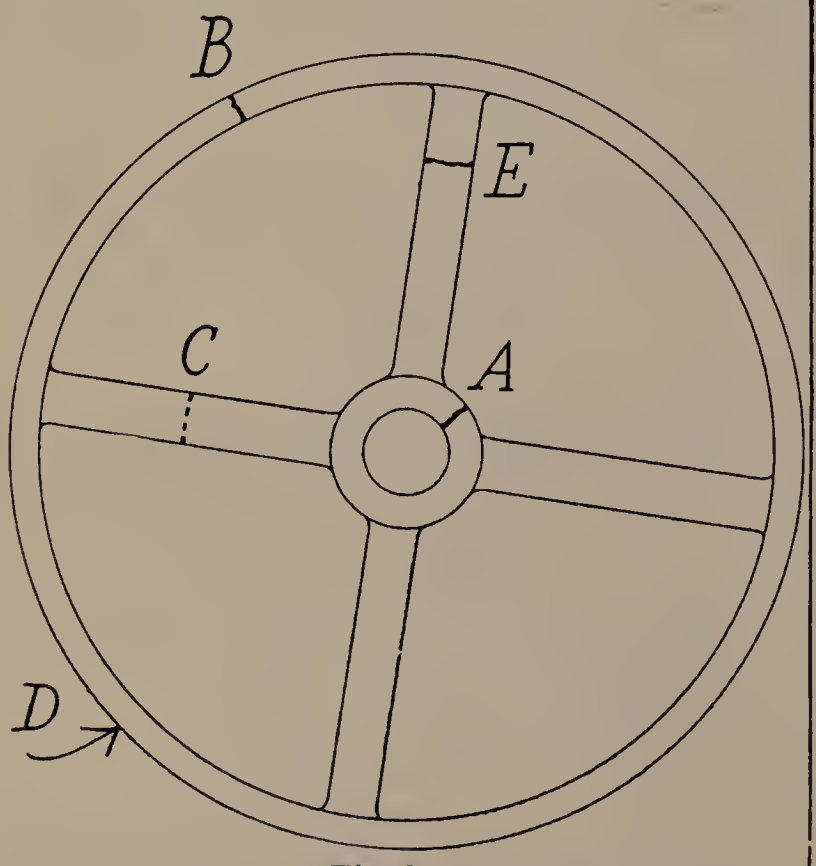


Fig. 6.

In selecting charcoal for preheating purposes the welder is advised to choose hardwood grades, which burn more uniformly and with less smoke, fumes, etc., and requires no blast.

No general rule can be given for preheating temperatures, as the degree of heat necessary will of course depend upon the size and shape of the object to be welded. As a general rule, however, cast iron should

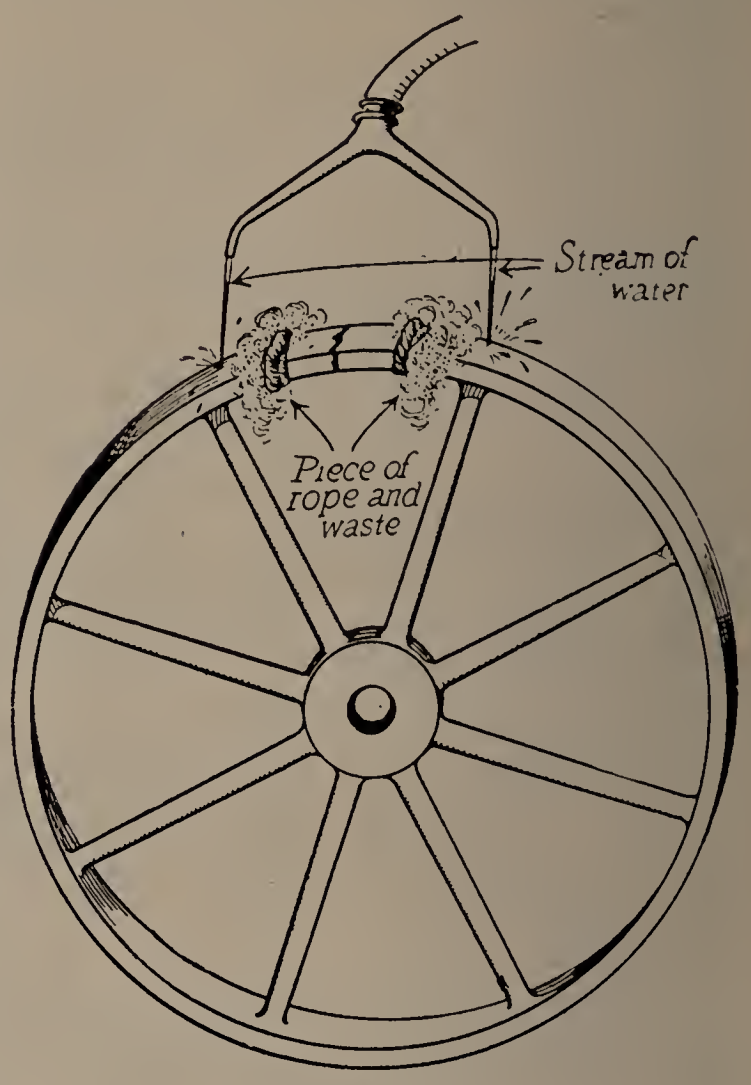


Fig. 7.

be preheated to a red heat. Brass and bronze, on the other hand, should not be preheated to more than a very dull red, which might be barely visible in the dark. Aluminum should be preheated very care-

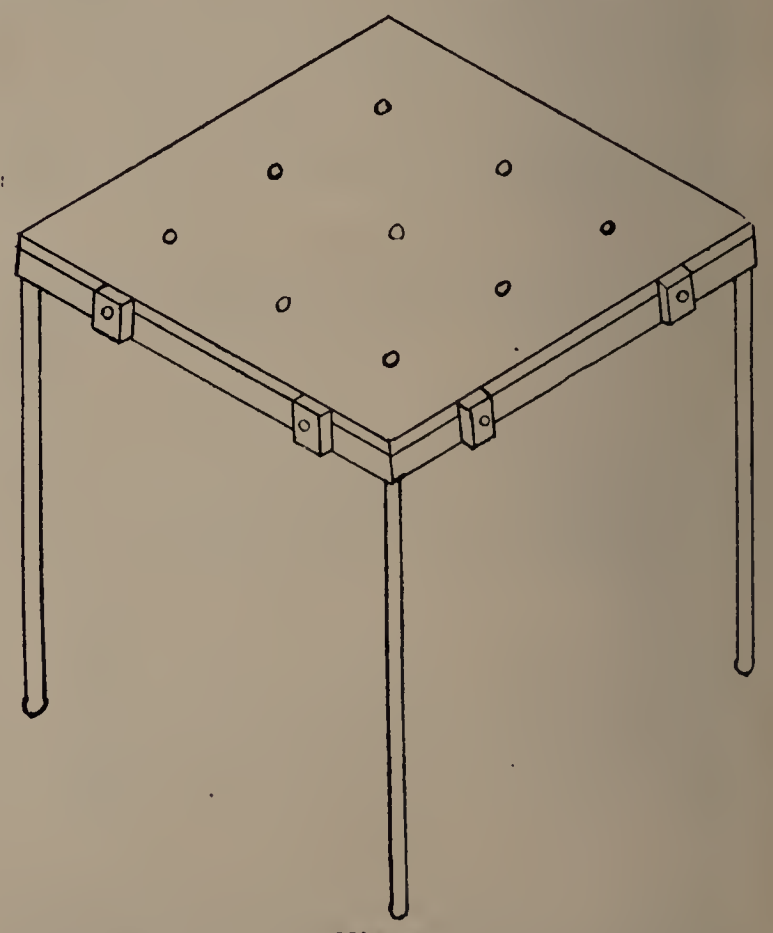


Fig. 8.

fully, as too much heat will surely result in the collapse of the article being heated. Aluminum should only be heated to the point where a solder made of one-half tin

and one-half lead melts when rubbed on the heated metal. This would mean a temperature of from 600 to 800 degrees F. Very few welding shops are equipped with permanent heat treatment furnaces and pyrometers, therefore it is useless to speak in terms of degrees, but temperatures must be described by colors. Every welding shop, however, should include in its equipment such a furnace, with heat measuring instruments, and for certain classes of work such equipment would certainly eliminate much guess work.

For the benefit of the novice we will illustrate some reasons for the necessity of pre-

Fig. 9.

heating. Fig. 1 shows a plain bar which has been fractured in the middle. When the bar is welded at A the two ends of the bar, B and B, will expand, but as there is nothing to prevent free play of the ends of the bar, there is, of course, no necessity for preheating. Place this same bar in the frame shown in Fig. 2, however, and we have an entirely different problem. When the bar is heated at the point A it is quite evident that there will be a strain at the points B and B and the side members of the frame, E and E, must either break or bulge.

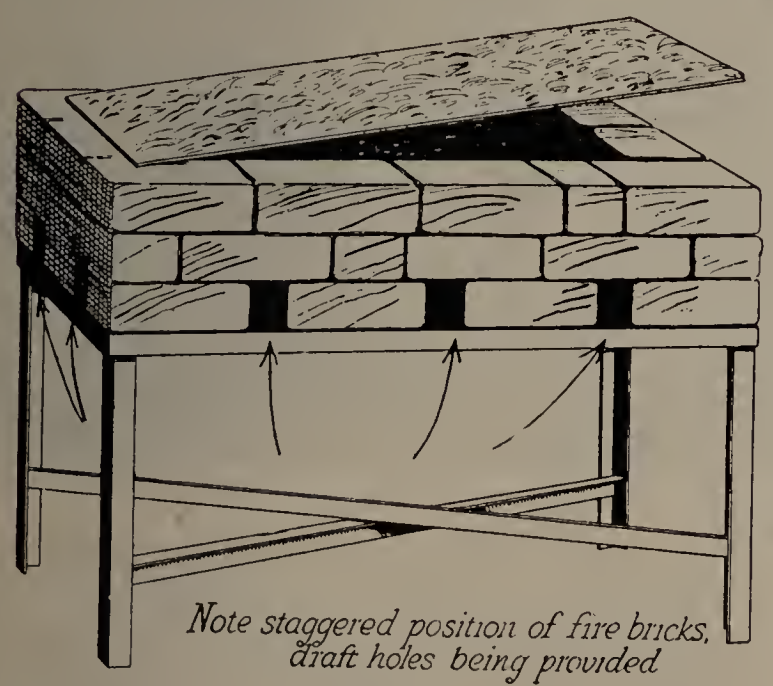


Fig. 10.

If, however, we preheated at the points C and C the frame would be expanded in the direction in which the strain would occur, the crack at A would open up and the welding and points C and C would expand and contract in unison.

Provision for contraction and expansion strains in wheels, pulleys, etc., may be made by localizing the heat or by preheating the entire object. Spokes in wheels which are welded without the necessary preheating will break when cooling, or the rim will either break or be pulled out of shape. Fig. 3 illustrates a broken spoke in a fly wheel. If the spoke was to be welded without the necessary preheating the results would be as just described. If the rim of the wheel, however, was to be preheated at the points A and B the rim would expand outwardly, thus opening up the broken spoke at C. When expanded the welding operation should be performed as quickly as possible, after which the three points to which heat has been applied should be allowed to cool slowly. Unless the wheel is of a very heavy construction it is usually sufficient to expand the rim to a point where a hack-saw blade can be inserted into the crack. This usually holds good in the case of wheels up to 30 inches in diameter.

When a spoke in a wheel is heated the strain caused by expansion occurs in a restricted area. In the case of a break in a rim, however, the strain is distributed over a greater area. It is therefore, possible to weld a rim break of this kind without preheating, and, as stated, the strain being distributed over a greater area, the weld **may** hold. An internal strain exists, however, and the wheel will probably break again, not necessarily in the weld itself, but at any point in the rim.

One good method of expanding the rim is illustrated in Fig. 4. Heat the wheel at point B, the hub, and with very little heat at B plenty of expansion will be secured at A. The amount of expansion required will, as previously explained, be determined by the size of the rim. The welder requires but little experience with wheels of varying sizes to determine the amount of expansion needed. In executing the aforementioned weld when sufficient expansion has been secured the weld should be made as rapidly as possible. Do not permit the hub to grow cold immediately, but keep it hot until the weld is completed, when it should be allowed to cool naturally.

In the case of a broken pulley wheel with a thin rim, the rim may be sprung by placing a jack between the spokes to secure the necessary space in the break, as illustrated in Fig. 5. A heavy wheel with a thick rim should not, however, be treated in this manner.

Fig. 6 illustrates a fly-wheel which is broken at three points, in the hub at A, in a spoke at E, and in the rim at B. Let us assume that this wheel is about five feet in diameter, the hub has a six inch bore and is three inches thick. The rim is about 12"x2" and the spokes are oval, approximately 6"x2". The first step should be to weld the hub at A. This weld could be

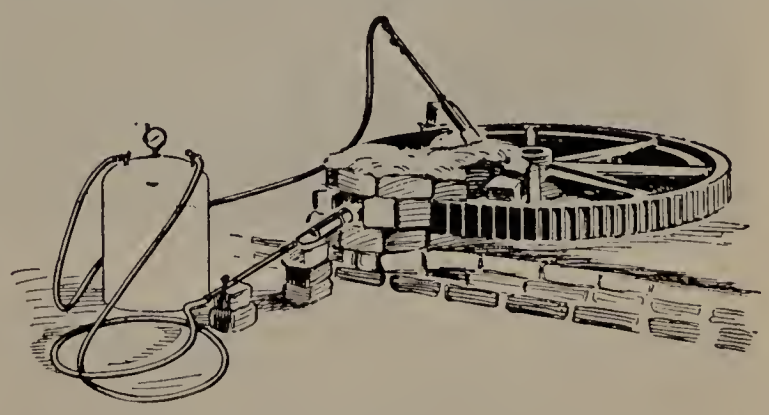


Fig. 11.

made without preheating at this point, if done fast, but the average operator would doubtless meet with more success by preheating. The spoke E should be welded next, after which the rim should be welded at B.

In welding broken spokes the welder should be careful not to preheat to the extent that the expansion will be so great

that the weld, when the spoke contracts, will be overcharged. When this occurs the rim is unable to return to its normal position and an untrue wheel, containing internal strains, is the result. Fig. 7 illustrates an emergency method of compensat-

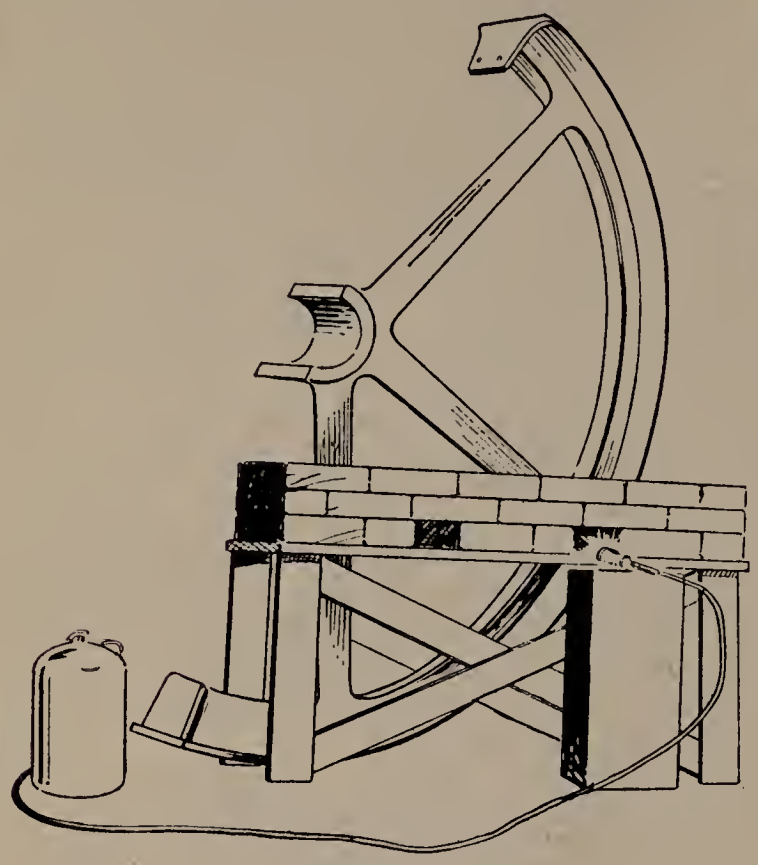


Fig. 12.

ing for expansion. Jets of water may be played on the object being preheated, at points on each side of the weld. Wet asbestos has also been used for this purpose. This is bad practice, however, and should only be attempted in emergencies, or where proper preheating is impossible. Where the chill occurs a transformation takes place in the metal and a brittle or hard section is apt to result. It is doubtful, too, if the effect of expansion can be sufficiently overcome by this method.

A small welding table, upon which a preheating furnace for treating small objects is illustrated in Fig. 8. This table may be constructed by the welder. The legs and frame may be made from 1½ inch angle iron, or one inch pipe, and the top may be of steel plate or cast iron. If of steel, the top should be at least ½ inch in thickness and if of cast iron at least ¾ inch or better. It may have one inch holes for clamping work to the table. Small clips, bolted or welded to the angle iron, two to each side, and level with the top of the table, will keep the top in place. A planed metal top is desirable in a welding table, if work is to be lined up accurately. An old planer bed oftentimes answers this purpose and they may be found in scrap iron yards. They may be mounted in any one of several good methods which will, no doubt, occur to the welder.

Fig. 9 illustrates a larger welding table which is very convenient. It is 30 inches wide and 6 feet long. It is long enough to line up automobile axles on and on ordinary work from two to four men can work at this table. The top and edges are planed, and with the two sets of angle plates and V blocks shown, almost any job of lining or testing may be handled.

Care should be taken to keep the welding table in good condition and it should not be overheated. Work should not be welded directly on the table, but should be blocked up off the surface.

If we are to consider a small furnace, such as might be constructed on a small welding table, the furnace shown in Fig. 10 will answer. The staggered position of the fire

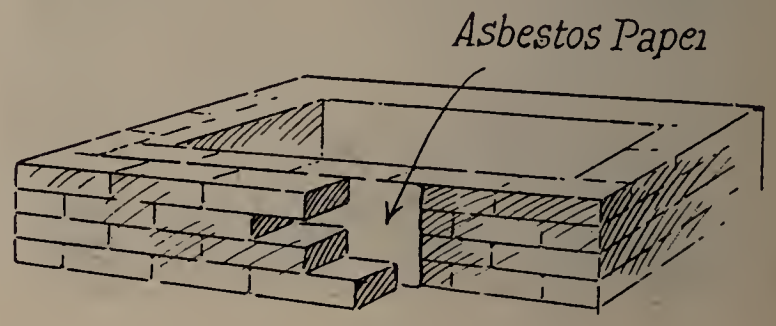


Fig. 14.

brick in the bottom row will be noted. This provides a suitable number of draft holes, a charcoal fire will burn readily with but little draft. In constructing the furnace provision should be made for replenishing the fuel, if charcoal is to be used, but this can usually be done from the top.

If the object to be welded, however, is too big or bulky to be placed on the welding table, then it must be welded on the floor of the shop or the job must be done in the most convenient place possible. The welding shop should have a welding platform, either level with or slightly raised from the floor, for handling large objects. Unless the shop is otherwise provided with excellent ventilation, a blower system should be installed to carry away objectionable smoke and gases.

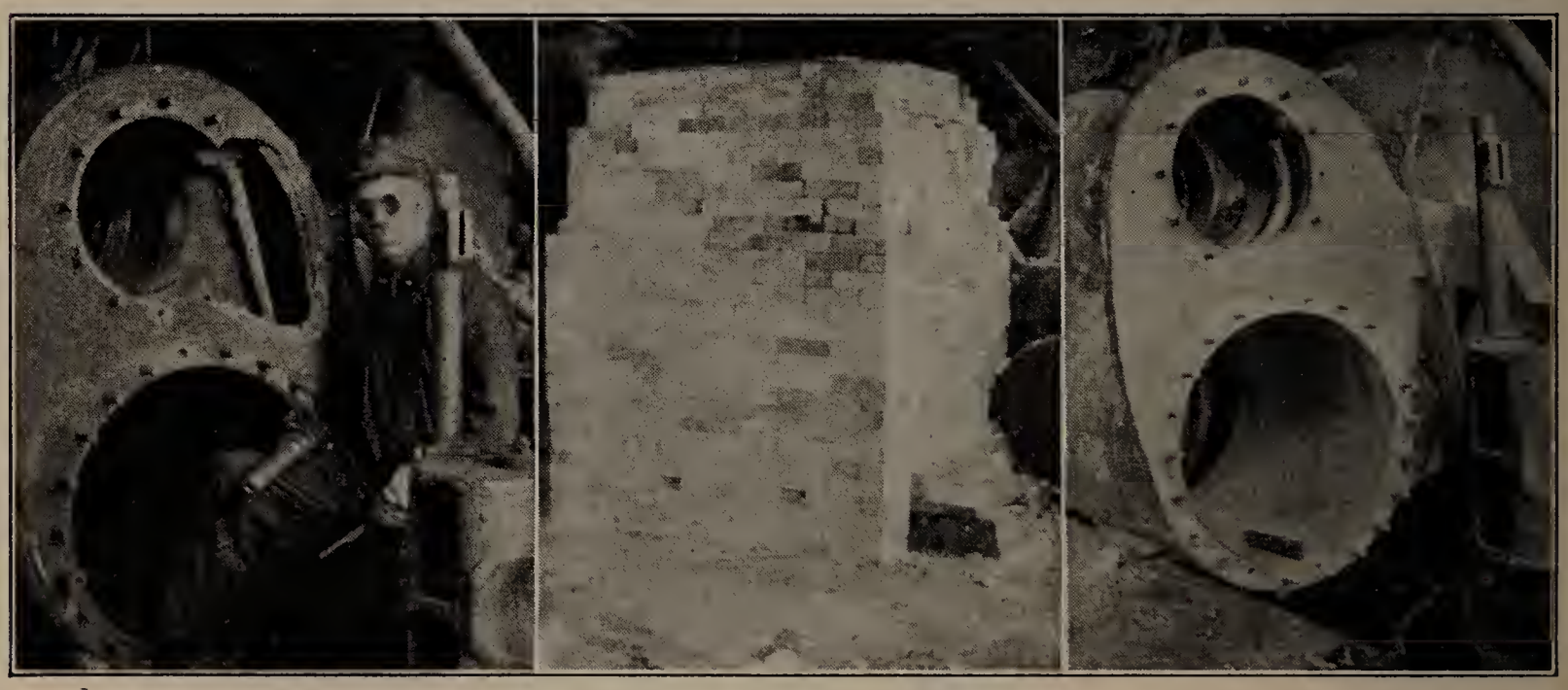


Fig. 13.

The space left for fuel displacement will, of course, depend upon the size of the object to be preheated. Fuel holes should be cov-

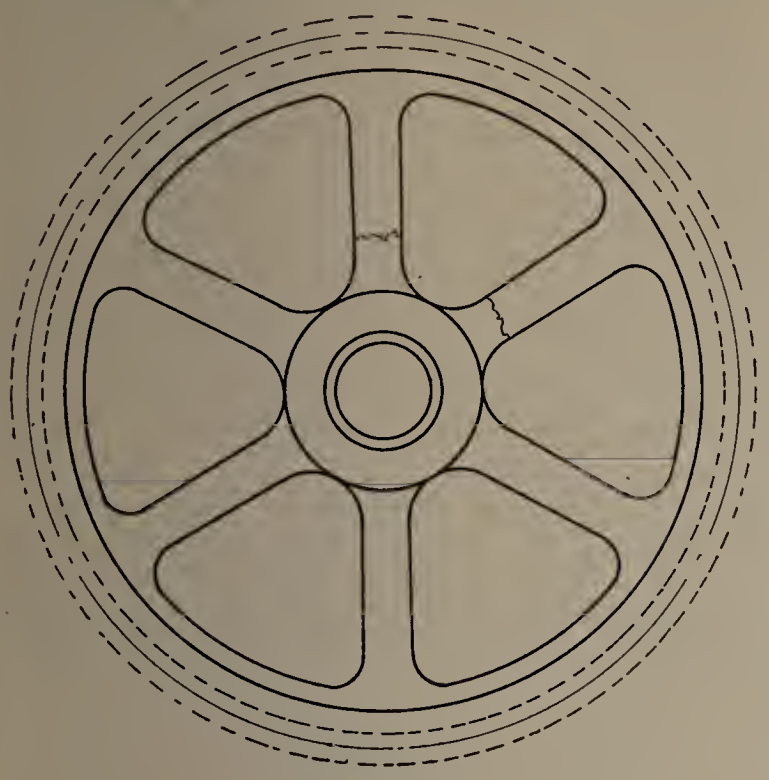


Fig. 15.

ered up or plugged up with fire clay when the fire is under way.

As a top for a furnace of this kind many welders use a piece of sheet iron, which answers the purpose very well, but which is not as economical as a piece of high grade asbestos welding paper. The asbestos will prove more efficient in restricting the heat to the furnace. A good grade of asbestos paper will not smoke or give out obnoxious fumes. It might be said the object in covering or protecting an object which is being preheated is to conserve heat, or confine the heat to the object. If the object to be welded was to be preheated uncovered, or without protection, there would be too great a loss of heat, with the additional danger of the object being chilled.

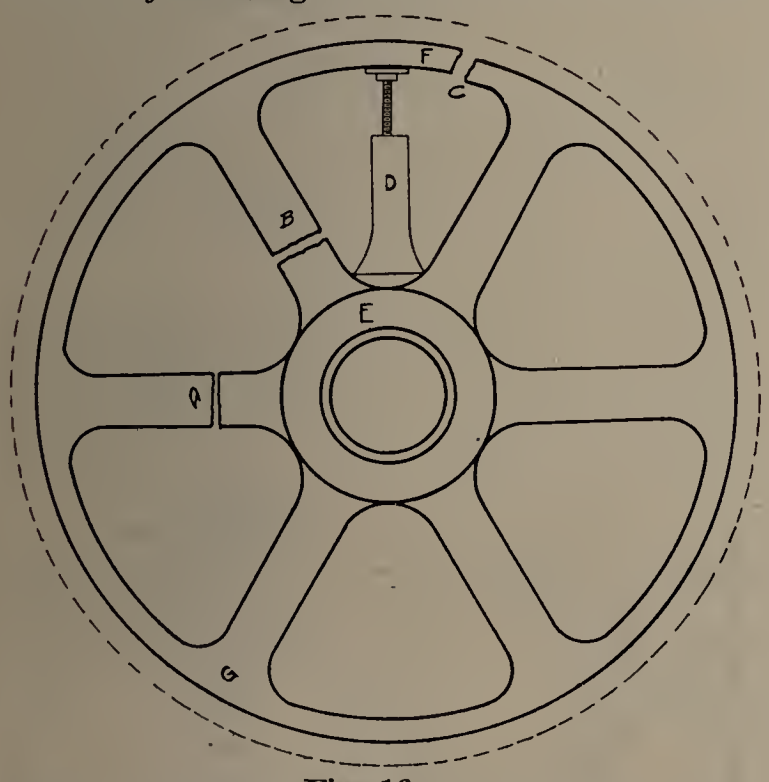


Fig. 16.

Fig. 11 illustrates a method of preheating the rim of a gear wheel, an oil burning preheating torch being used. Fig. 12 illustrates a method of building a preheating furnace on a scaffold, where work cannot be laid flat. Fig. 13 illustrates the proper method of constructing a preheating furnace around a locomotive cylinder in place. At the left we see the broken cylinder, in the center the furnace, and at the right the finished job. See "Expansion," "Contraction" and "Carbon."

and these holes may be readily closed with fire clay. In building a furnace of this type provision may also be made for openings

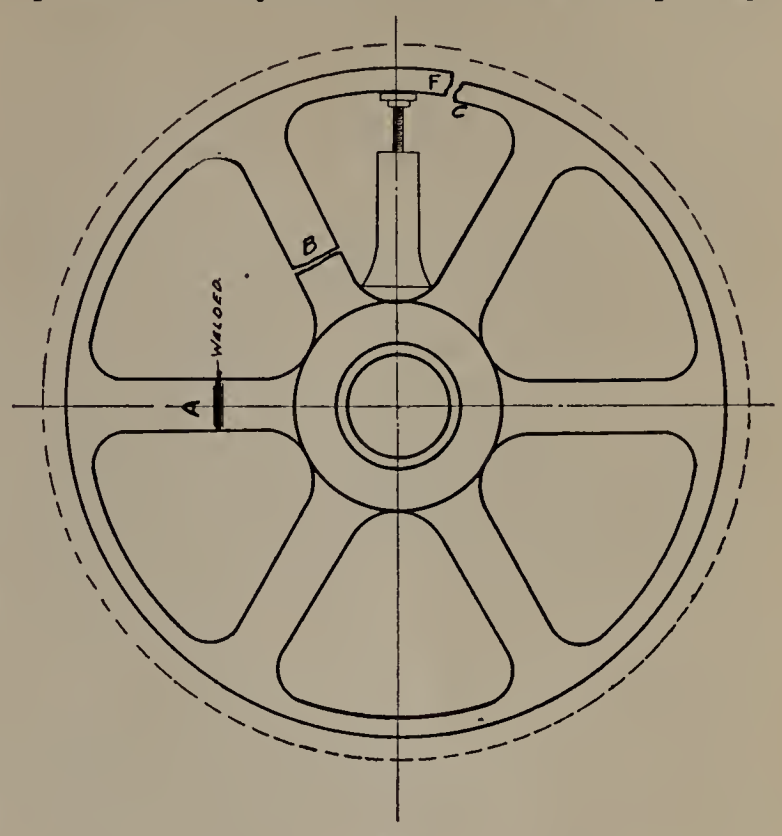


Fig. 17.

for preheating torches at desired locations. It should be remembered that, once started,

On large jobs it is often worth while to make the preheating oven in two layers, with asbestos paper between, as shown in Fig. 14. This double wall with the asbestos paper between serves the double purpose of keeping the heat in and protecting the welder.

Mechanical Expansion

Sometimes the question of speed is paramount in the repair of a broken casting and preheating is therefore displaced by pre-expansion by mechanical means. Figures 15 to 18 show how this was done on a large

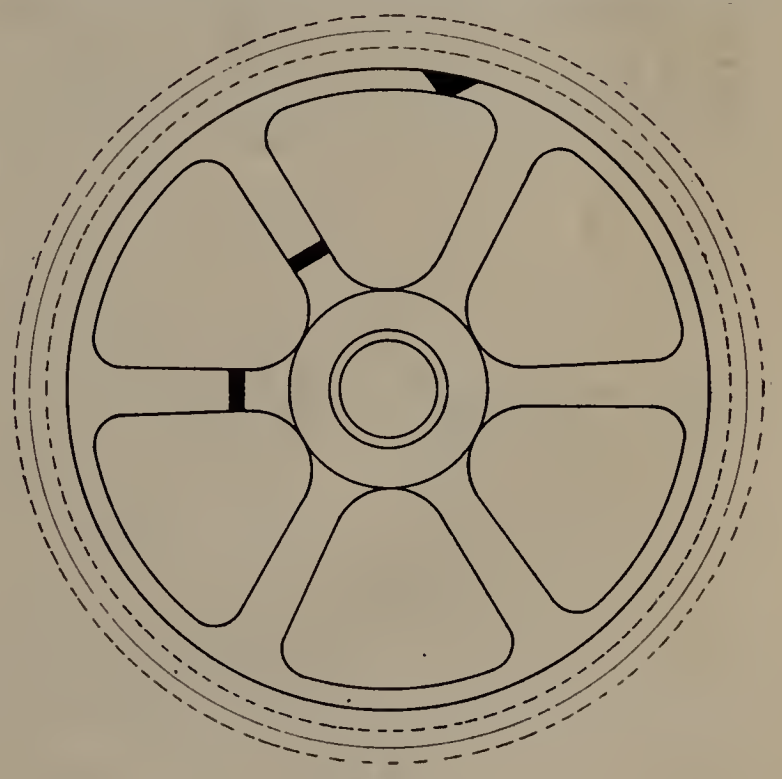


Fig. 18.

spur gear, broken in three places. The weld on the rim was 12 inches wide by 2½ inches thick, and the welds on the spokes were 6 inches wide by 1½ inches thick.

A worm screw jack (D) was placed between the hub of the gear and the face or rim (E and F) and tightened up until the opening at fracture (A) was about $\frac{3}{32}$-inch wide. That left an opening at second fracture (B) about $\frac{3}{16}$-inch wide, also opened fracture on face or rim (C) about ¾-inch wide and about the same distance high, and

is all clearly shown on Fig. 16. This being a large gear and a wide face or rim, there wasn't any chance of setting up any undue strain at spoke marked (G), as the distance from the face or rim fracture (F) to the first solid spoke (G) was about 8 feet, this distance giving quite a leverage to take care of the openings caused by the jack. This scheme created the same condition that would have been obtained by preheating the wheel.

Instead of bevelling this fracture to a 45 degree angle with a chisel prior to welding, it was melted out with the welding torch, and while this was not the cheapest way, it surely was the quickest and most advantageous as the spoke on both sides of the fracture expanded, due to the heat of the melting out process and shortened up the $\frac{3}{32}$-inch opening to about $\frac{1}{32}$-inch, and as soon as the fracture was melted out to as near a 45 degree angle as the eye could determine, welding was started. The entire bottom of this fracture was welded, adding only enough metal to prevent the molten metal from flowing through, when the jack was loosened up to allow for contraction and weld completed.

While the weld on spoke (A) Fig. 17 was cooling the fracture on spoke (B) was being melted out the same as was done before, and just as soon as the opening at (B) was about $\frac{1}{16}$-inch wide, the jack was again put in place (Fig. 17), and welding was commenced. While progressing spoke (A) was kept warm by playing heat from torch on weld every few minutes to keep it partly expanded until weld at B was completed, when jack was taken away entirely and both welds allowed to cool at one and the same time. After both welds were cold the fracture on face F had come nicely together, so the welder drove a cold chisel into the fracture to spread it apart about $\frac{1}{32}$ inch, when both sides of fracture were melted to a 45 degree angle and welding started.

As soon as the fracture was tacked on the furthest side from the chisel, it was taken out and weld completed as per Figure 18.

A considerable quantity of aluminum repair work will call for the use of a preheating device which is easily put into operation and which does not supply too heavy a flame. Such a device can be constructed from a Bunsen Burner after the fashion in-

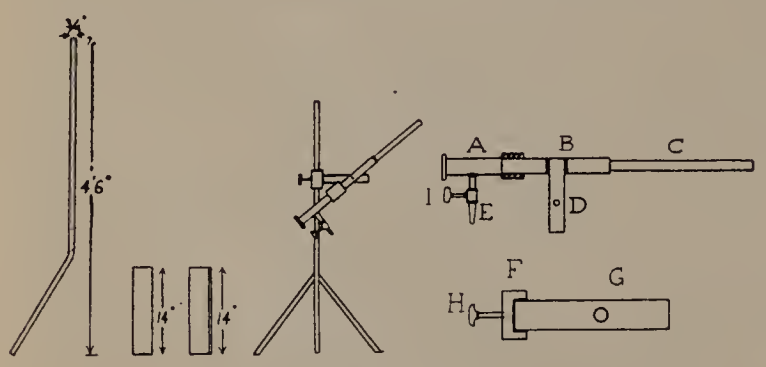


Fig. 19.

dicated in Figure 19. The details of this preheating arrangement are as follows:

A—Angle Bunsen Burner, ½" inlet, 1¼" outlet.

B—1¼" pipe, 9" long, screwed to Bunsen Burner.

C—1" pipe, 12" long welded onto end of 1¼" pipe.

D—¼"x¼"x6" strap welded onto 1¼" pipe, drilled for ⅜" bolt.

E—½" Hose connection screwed into valve of burner.

F—1" thimble, 2" long.

G—¼"x1¼"x6" strap welded on thimble. Straps drilled for ⅜" bolt.

H—⅜" set screw with wing nut.

I—½" Valve on Burner.

Figure 20 shows how a small portable oven can be made from sheet metal to be placed over small castings such as motor heads while they are in the preheating fire. A fire brick is placed under each corner of the casting to be welded and this oven is placed over all. Two holes are cut into the top of the oven to provide good circulation of the flames.

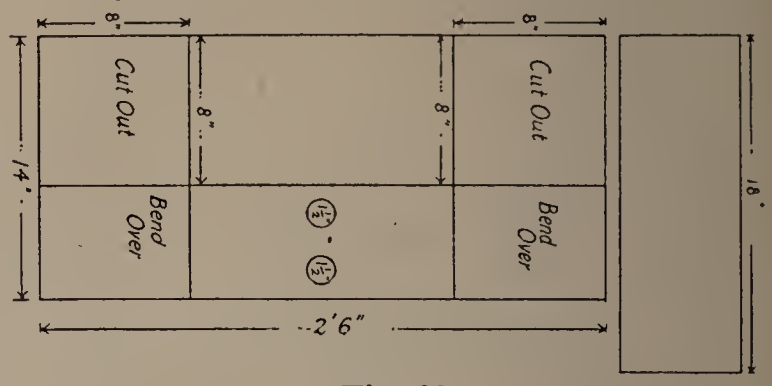


Fig. 20.

Fig. 21 shows an aluminum crank case in which the center bearing has been case in which the center bearing has been broken. This has always been considered a difficult job for the average welder, but

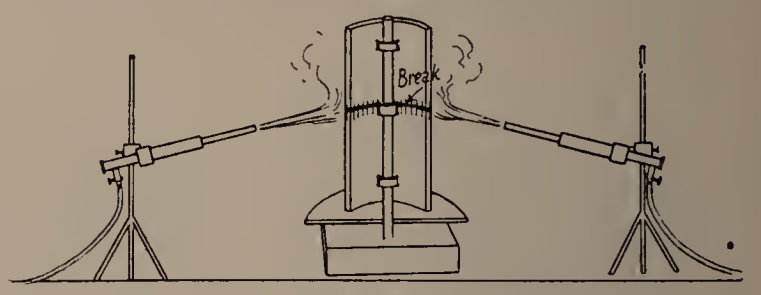


Fig. 21.

the following procedure is simple and effective. Procure a tube to fit the center bearings snugly. Put back the top bearing caps and tighten down enough so that the tube will not turn by hand. No shaft will be required in the cam shaft bearings, as these will not get out of alignment. Place the crank case on end over a box, or better still on an angle iron square frame so that the tube may not rest on anything. Place two heaters as shown. Put on a gentle flame for a couple of minutes, and then open up the gas. In about ten minutes it is ready for welding. After finishing the top side turn it upside down and finish the bottom side. Of course the position of the burners has to be readjusted for the second operation. After welding, reduce the flame enough to keep it only fairly hot for about five minutes. This prevents any cracking due to sudden shrinkage.

Fig. 22 shows the construction of a combination preheating and welding table. The only new articles necessary to buy are two kerosene burners. The oven shown in the center of the table is filled with coke and the two kerosene burners supply additional heat through the pipes.

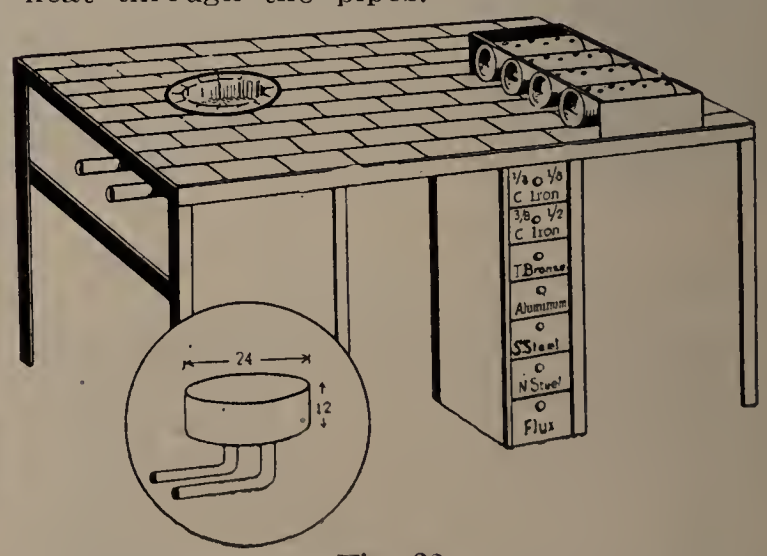


Fig. 22.

The arrangement at the end of the table consists of four lengths of 16-in. pipe, laid side by side and welded together. Holes are cut in the top of the pipe and they are

filled with broken fire brick. This preheater is for cylinder blocks and crank cases and is so arranged that the heat can be located where desired by shifting the blaze to different pipes.

One of the most difficult problems confronting the welding department in the railroad car shop is that of building up on the threads and flanges of worn wheels.

It does not appear to be economical to remove wheels from axles for the purpose of building up the worn areas, so annealing or preheating to a high temperature is not practicable, but continuous welding on cold metal subjects the metal to repetitions of expansions and contractions, resulting in cracks. The danger of failure is increased by the fact that stresses are often left in the wheel during the manufacturing process.

A favorite method of building up worn wheels is to interrupt the continuity of the weld and let a small section of the deposited metal cool while more metal is being added on a portion of the wheel a considerable distance from the first deposit. The biggest drawback with this, is that results are fairly uncertain.

A less desirable practice is that of keeping the wheel cool during the welding operation by immersing it in water except for the small portion which is left exposed to the action of the electrode.

The latest development toward the solution of the entire problem is found in a method for which the Westinghouse Electric & Mfg. Co. has a patent pending. The principal feature of the process is the selective heating of parts of the wheel before, during and after the deposition of metal by automatic continuous arc welding. The wheels are mounted on the axle, and the axle is suspended on the center of a lathe. (Fig. 23). A pair of semi-circular burners are attached to the wheel and are set approximately one-fourth the radial distance of the plate or between the hub and rim, and close to the concave side of the plate. If the heating is done by gas, a ½-in. pipe is used, drilled with three $\frac{1}{16}$-in. holes at a 45° angle around the inner part of the circumference, directing the flame against the hub plate and rim of the wheel.

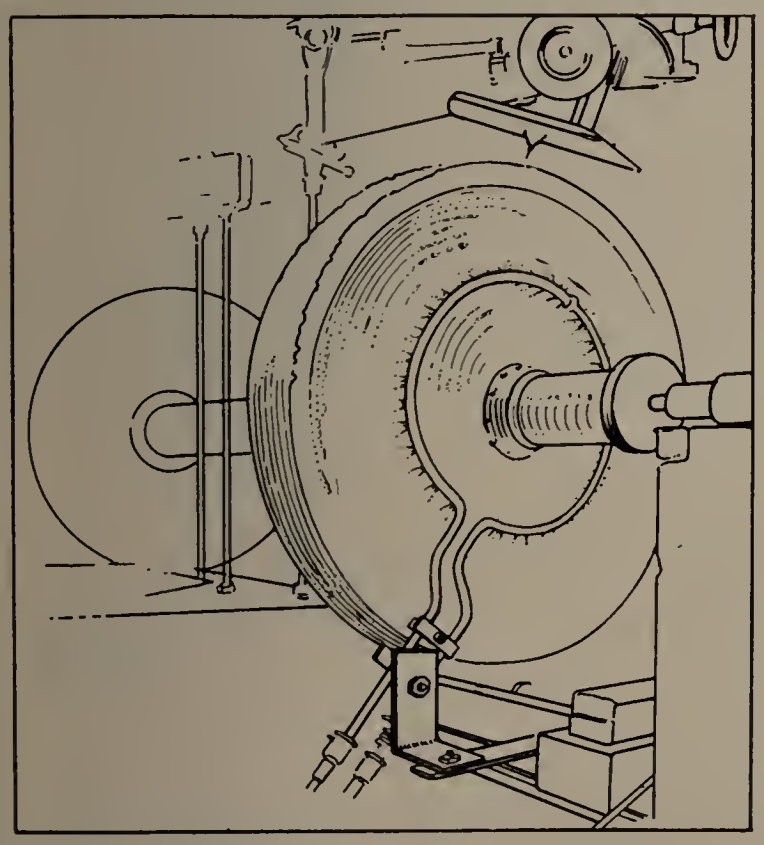


Fig. 23.

The wheel is heated to approximately 480° F. before the welding is started. The first layer of strands is deposited on the tread, and the temperature of the wheel is gradually increased to between 660° and 840°, care being taken not to exceed the latter temperature. The second and third layers are deposited while the wheel is kept at this heat, and the flange is built up, the temperature gradually being reduced to a temperature of 420° F. When the welding is finished the heating is turned down, so that the temperature of the plate falls to 840°. The heat in the rim and the hub is allowed to cool to where the hand can touch the wheel without danger of being burned, then the heat is turned off entirely and the whole wheel is allowed to cool to room temperature. The second and third layers of deposited metal are much hotter on this 37-in. wheel than when put on a cold wheel, and on cooling they contract to the natural dimensions of the wheel with the rest of the metal, without subjecting the wheel to abnormal and combined stresses.

Pre-Ignition
The burning of the mixed gases at some point within the torch caused by overheating. From a practical standpoint this term is covered by the definition of flashback. See Flashback, Back Fire and Flame Propagation.

Pressure
A term used to express the force exerted by confined gas. Pressure is measured in pounds per square inch.

Pressure Contact Weld
See under "Butt Welding" in chapter on "Electric Resistance Welding."

Pressure Reducer
A device intended to reduce and regulate the pressure of gases used for welding and cutting.

Pressure Regulator
A device intended to maintain a nearly constant pressure of gases. Pressure regulators are sometimes called reducing valves. They are used to lower the pressure of gas from the source of supply—cylinders, generators or pipe line systems—to the working pressure necessary. See "Regulator."

"Prest-O-Lite"
Trade name for compressed acetylene in tanks. Made by Prest-O-Lite Co., Carbide and Carbon Bldg., New York, N. Y. See Table of Contents, "Catalog Section."

Primary Leads
Wires connecting primary windings of the transformer of an electric welding machine (for arc or resistance welding), with the shop circuit.

Projection Welding
See "Point Welding."

Propane
A hydro-carbon gas. The chemical symbol is C_3H_8.

"Protexsite"
Trade name for welding goggles, shields and helmets. Made by the Safety Equipment Service Co., 1104 Hamilton Ave., N. E., Cleveland, Ohio.

"Protexal"
Trade name for protective clothing for welders. Made by Strong, Kennard & Nutt Co., 2044 E. 9th St., Cleveland, Ohio.

Publications, Welding
The following are the principal journals of the North American continent treating on the subject of autogenous welding:

United States

The Acetylene Journal:
Published monthly by the Acetylene Journal Publishing Co., Peoples Gas Bldg., Chicago, Ill. Official organ of the International Acetylene Association. Price two dollars per year. Devoted to Acetylene Lighting and Welding.

The Welding Engineer:
Published monthly by The Welding Engineer Publishing Co., 608 S. Dearborn St., Chicago, Ill. Price three dollars per year. Devoted exclusively to the subject of autogenous welding by all methods. See Table of Contents, Catalog Section.

Journal of the American Welding Society
Published monthly by the American Welding Society, 33 W. 39th St., New York. Sent free to members. Devoted to proceedings of the society.

Canada

The Canadian Welding Journal:
Published monthly by The Wilcox-Robinson Publishing Co., 12 Johnston St., Toronto, Canada. Price two dollars per year. Devoted exclusively to the subject of autogenous welding by all methods.

Puddle
See "Pool."

Puddle Stick
A steel rod fastened at the end for breaking up oxides, removing slag, impurities, etc., in aluminum welds. The Puddle Stick is used especially when welding cast aluminum without a flux.

Puddling
A method of welding aluminum.

Purifier
A device or apparatus for removing sulphurreted hydrogen and other gases from acetylene.

"Purox"
Trade name for oxygen and hydrogen produced and distributed by the subsidiaries of Compressed Gas Corporation at Denver, Salt Lake City, Seattle, Oakland, San Francisco and Los Angeles. Also trade name for gas welding and cutting equipment made by California Compressed Gas Company, 2311 East Fifty-second Street, Los Angeles, California. See Table of Contents, Catalog Section.

"Pyrograph"
Trade name for mechanically operated oxy-acetylene cutting torch, formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

—Q—

"Quasi Arc"
Trade name for electric arc welding equipment, supplies, accessories, etc. Made by Quasi Arc Weldtrode Co., Peekskill, N. Y.

"Quick Cut"
Trade name for cutting torches. Made by Alexander Milburn Co., Baltimore, Md.

"Quick-Weld"
Trade name for welding torches. Made by Alexander Milburn Co., Baltimore, Md.

"Quinn-Aeroil"
Trade name for portable oil burning torches. Made by Aeroil Burner Co., Union Hill, N. J.

—R—

"Raco"
Trade name for mild steel and covered electrodes for electric welding, soft iron rods for oxy-acetylene welding and composite electrodes. Made by Reid-Avery Co., 1434 Brandywine St., Philadelphia, Pa. See Table of Contents. Catalog Section.

"Radiagraph"
Trade name for mechanically operated oxy-acetylene cutting torch, formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

Radiators (Automobile)
Automobile radiators are not usually repaired by welding, for there is so much soldering in the first construction, and the

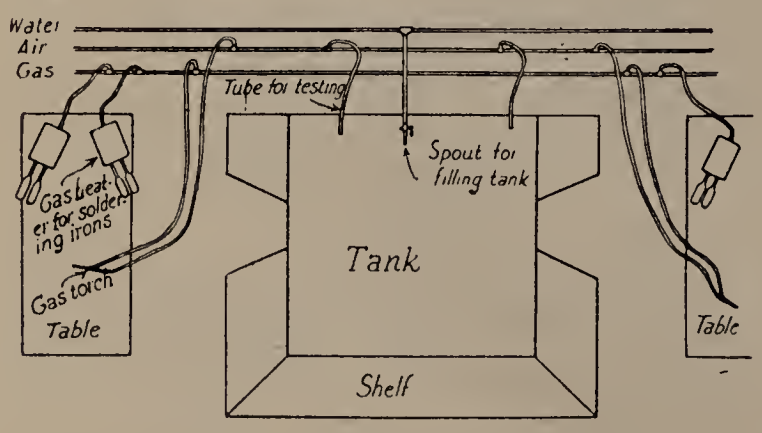


Fig. 1.

metal in them is usually of such light construction that the welded flame, even with a very light tip, is too hot, so the repair is a soldering process throughout. Many of these radiators, however, find their way to the welding shop, and there is good profit in repairing them, if only for the sake of keeping a customer in touch with the shop. Closing leaks in the shells or cores is only a simple soldering job, so in order to make this work profitable the welder has to provide a systematic method of handling the work. The diagram in Fig. 1 shows a testing tank with two working shelves and two tables for holding the soldering equipment. The tank should be made of two-inch planks and lined with galvanized iron. A shelf, of two-inch plank, extends around three sides of the tank, with openings on two opposite sides large enough to allow workmen

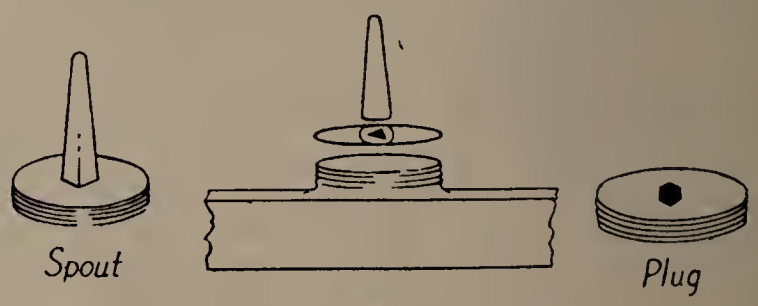


Fig. 2.

to stand close to the tank. This arrangement makes it possible to handle tanks in the water and lift them out without stretching.

Two soldering irons, and a small gas furnace for heating them, a small gas torch, and air hose for testing radiators, soldering flux, a small frame made of angle iron, pincers, solder sticks, and accessory tools should be provided for each repair station. In the layout illustrated there are three pipe lines,

carrying water, air and city gas. The water is used to keep the testing tank full. The air is used for testing radiators and for the gas torches. The gas is used for the soldering torches and for the small furnace which heats the soldering irons.

When a radiator is brought into the shop it is first tested to locate the leak or leaks. To do this it is placed on the shelf of the tank and plugged carefully. A set of standard plugs can be purchased that will fit a good many radiators, but if an odd size is found the openings are plugged by soldering discs of tin over them. The overflow outlet can be plugged with a drop of solder. One of the plugs is fitted with a spout air hose connection. The hose is attached to the radiator as shown in Fig. 2, the air turned on and

Fig. 3.

the radiator placed in the tank. Small bubbles immediately locate the leaks. The leaks that are most accessible are soldered with the iron. Those which are located in corners or inside the honeycombing are easily reached with wire solder and the gas torch. This gas torch is easily constructed from two pieces of small brass tubing, and using city gas with compressed air gives a flame that is hot enough to melt the solder without damaging the adjacent joints. The oxy-acetylene flame is both too hot and too expensive for this work.

From the time that the work is started until it is made air tight the radiator should be kept close to the tank, where the test can be made in a few seconds. Compressed air can be supplied from an air-compressor located at any convenient point in the shop.

Each workman should have a complete set of tools that he needs and a place to work so arranged that he can complete the repair without walking all over the shop to look for tools or materials, and without unnecessary handling of the radiator. That is, the arrangement and the system are time savers. This is very important because the work must not be allowed to drag. Most customers know that the work is a simple case of soldering and would resent the charge that would have to be made if the job were not handled quickly.

The ready-made plugs mentioned above save their cost in a week through the difference in time between inserting them and soldering on a tin disc. Figure 3 also shows how a spout can be made for a radiator which cannot be fitted with one of the standard sizes. A tin disc is soldered over the intake, a hole punched in the disc with a center punch, and a brass spout soldered over the hole.

Figure 2 shows the use of the small angle-iron stools for holding the radiators in position where soldering can be done comfortably.

Radiograph

An X-ray photograph. Used to some extent in testing welds. It gives only the gross structure of the metal, such as the presence of blowholes, slag inclusions, porous spots, and defects of like nature which could not be found otherwise, except by cutting into the metal.

"Railox"

Trade name for high carbon steel welding rod for acetylene or electric welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

Reactor

Frequently called Stabilizer. An inductive coil of copper wire or strap surrounded by a laminated iron circuit provided with an air gap. The reactor delays rate of change of current and stores electro-magnetic energy. The first feature enables the operator to strike the metallic electrode arc more easily because the tendency of electrode to freeze to work is minimized. The second feature gives the arc additional stability, counteracting any influences which tend to extinguish the metallic electrode arc such as air drafts, and gas formation due to impurities in metal being welded. The carbon or graphite electrode is not subject to freezing and the arc is much more stable than the metallic electrode arc, therefore it is not necessary or advisable to use a reactor in such circuits.

Reaction

The chemical or mechanical change resulting from a combination of gases, liquids or metals.

Recession

The distance between the original scarf line and the average depth of penetration parallel to this line obtained in the completed weld.

"Red Head"

Trade name for oxygen, acetylene and welding supplies. Made by The Gas Products Co., Columbus, Ohio. See Table of Contents, Catalog Section.

Reducing

A term usually applied to flame, meaning carbonizing or carburizing—the opposite of oxidizing.

Reducing Flame

See "Carbonizing Flame."

Reducing Valve

See "Regulator."

Re-Entrant Angle

The angle between the surface of the parent metal and the overlapping unfused edge of the deposited metal. This angle should not be more than $\frac{1}{16}$" deep.

Refrigerating Machinery

Manufacturers of refrigeration machinery have experimented with various types of packed joints, threaded joints, forged fittings and caulking in an endeavor to avoid leaks in the anhydrous ammonia pipe lines and receivers, and have met with little success until the adoption of the welded joint. The welding commonly required in this industry falls naturally into the classifications of pipe welding and tank welding, but enough experimental and practical work has been done on the special shapes needed in

Fig. 1.

refrigerating plants to furnish some useful material to the refrigerating engineer.

The important parts of refrigerating machinery which are commonly welded fall into a general classification of pressure containers and it is universally considered that the preparation and construction of the work

for pressure welding is fully as important as the adjustment of the flame or electric current, the manipulation of the torch, the electrode, etc.

For example, in welding longitudinal seams on round tanks, it is first necessary to have a perfectly round shell. This means that the joining ends of the sheet shall not have a flattened section, as customary when coming from the bending rolls. The reason for this is that the flattened edges come together to form a peaked looking joint which

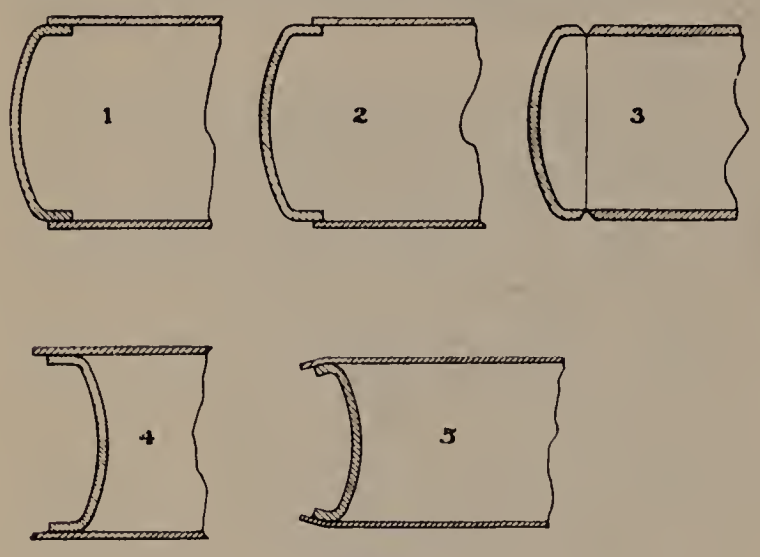


Fig. 2.

has a tendency to round out under pressure and in so doing exert a wedging action on the weld which is often the cause of rupture.

Another vital point in welding refrigerating machinery is the problem of expansion and contraction. When a longitudinal seam is started at one end of a shell, it is important to have the edges of the sheet on the far end spread apart. The object is to allow the molten metal which is then at its most expanded state, to shrink and gradually bring the edges together as the weld is progressing, thereby avoiding shrinkage strains as much as possible. The proper amount of opening for acetylene welding should equal the thickness of the sheet per foot of length. For electric arc welding one half of this is usually enough. Another point in procedure which will avoid the bad effects of shrinkage strains is to make the entire seam at one filling in.

Five types of heads for cylindrical pressure containers are illustrated in Figure 2. The first type shows the head put in convex. It is so far pushed into the shell that the weld is in a position where it is subject to a bending strain which should be

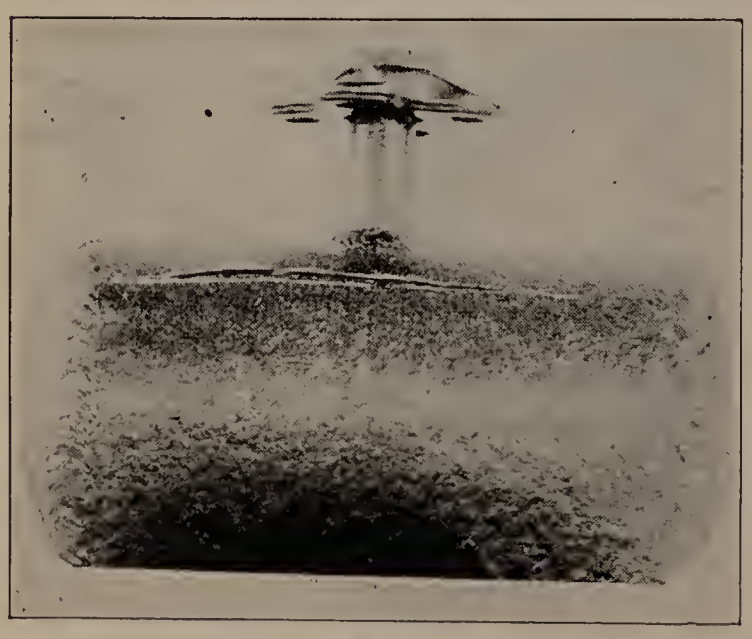


Fig. 3.

avoided as much as possible. The same construction is shown in the second type with the exception that the line of welding has been moved farther down on the flanged part of the head and is therefore in tension only.

The third design is a simple butt welded head which leaves the weld in tension. The head is put in concave in the fourth design so that the weld is in compression. Therefore, as far as the working strength of the weld is concerned, this is the better construction. A more expensive type of construction is shown in the fifth design where

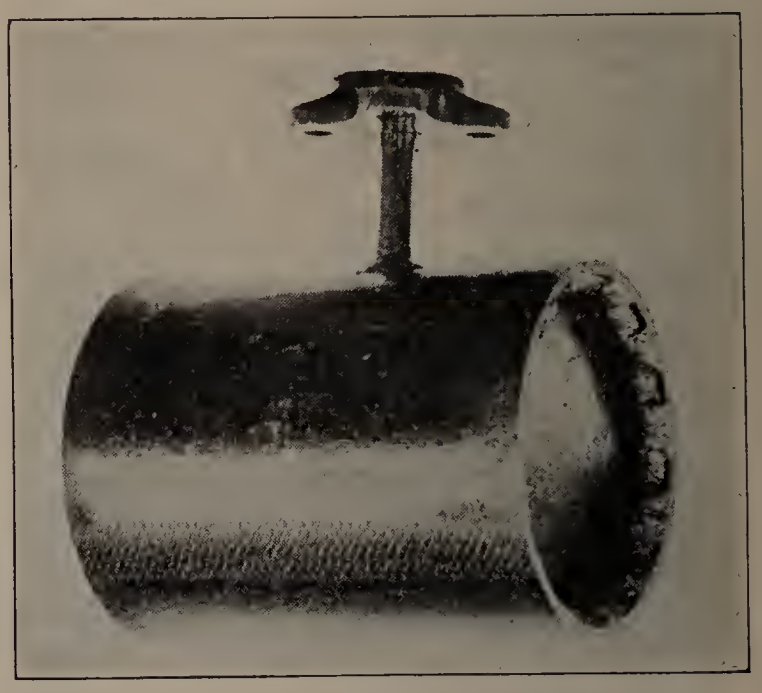


Fig. 4.

the head is put in concave and the end of the cylinder tapered down.

So far as depending on the weld is concerned, this is considered by many designers to be the best of the lot.

A 6″ lap welded pipe of common thickness with both heads welded in convex by the electric arc process is shown in Figure 3. A 1″ nipple was also welded in it to receive hydraulic pressure. After raising the pressure to 3300 pounds per square inch, the pipe opened up in the lap welded seam for almost the entire length except 1″ from one end and 2½″ from the other indicating that the weld around the heads held the pipe from ripping way across. In welding these heads, no special care was taken to make an extra good job. This test alone would indicate that since lap welded pipe as made by all pipe mills is universally accepted as safe construction, electrical and gas welding are entitled to the same confidence.

A piece of 8″ common pipe is shown in Figure 4 with both heads welded in concave. Under test, at a pressure of 2600 pounds,

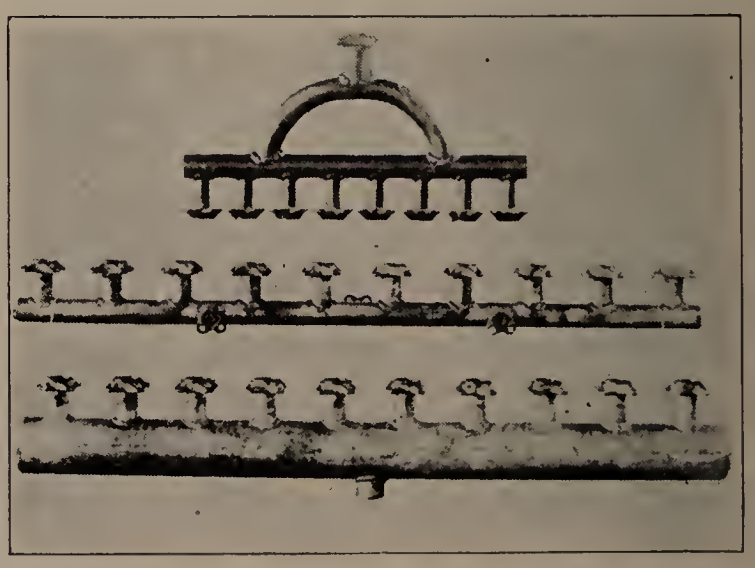


Fig. 5.

one head started to town outward or reversed the dishing. At this time, the pressure dropped down to 1600 pounds which was sufficient to completely turn the head to the outside.

Tests have recently been completed for the purpose of making a comparison between riveted heads and welded heads and these tests have shown plainly that welded heads are much stronger than the riveted ones. For example, a riveted tank in a test started to leak at all the rivets and seams at 1200 pounds pressure whereas the welded tank was perfectly tight up to the application of 1700 pounds.

The application of welding to actual work, which could not be made any other way

Fig. 6.

except welding, is shown in Figure 5. The top header is a 2½" pipe with a 1" nipples and 5" center distance. The close spacing of nipples would not permit fittings to be used. The two lower headers are made of 2½" and 6" black pipe and after welding have been galvanized, which also could not be done if made up by screwed fittings.

A welded steam receiver 24" in diameter is shown in Figure 6. This is made of ⅜" plate and is 6 feet long. The head is of ½" plate, one of the nipples is 6" in diameter and the other 8". A steel flange is welded on to one end to provide for bolting.

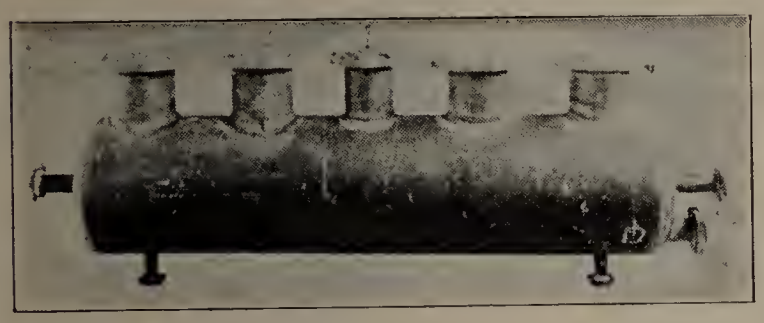


Fig. 7.

Figure 7 is an illustration of a suction drum for two compressors to equalize suction pressure. This is made of 24" pipe which has a half inch thickness and is 8 feet long. It carries four 10" nipples and 1" nipple.

The above illustrations will serve to show the variety of work which can be handled in the construction of refrigerating machinery by either the electric arc or oxy-acetylene welding. For detailed instructions on the actual welding procedure, the reader is advised to consult the chapters on Oxy-Acetylene welding, Electric Arc welding, Tank Welding and Pipe Welding.

"Rego"

Trade name for welding and cutting apparatus, torches, regulators, valves, lead burning and decarbonizing equipment. Made by The Bastian-Blessing Co., Austin and La Salle Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Regulations

Laws and regulations pertaining to the construction and operation of welding apparatus and allowable applications of the art will be found under "Rules and Regulations."

Regulators

Regulators in common use to reduce the pressure of gases are the so called diaphragm type. These regulators may be roughly divided into two classes, first where the pressure of the gas from the drum or generator closes the inlet and second, where the inlet is closed by the spring.

The first type has a seat or disc directly connected to the diaphragm, on the other side of which is a spring or springs. In operation, when the gas pressure within the regulator reaches a pressure greater than the tension of the springs, the springs are compressed and as the seat is directly connected with the diaphragm, it is forced against the inlet nozzle, shutting off the gas coming into the regulator. When some of the pressure in the regulator is used the spring again becomes stronger than the pressure in the regulator and the diaphragm is then forced in the opposite direction, thereby pushing the seat away from the inlet and again admitting gas to the regulator.

The second type of regulator is one in which the diaphragm acts only in opening the seat; not in closing it. The latter function is performed by a spring back of the seat, the tension of which forces it against the inlet nozzle.

With the first type the regulator, inasmuch as it is the pressure of the gas which closes the seat against the inlet nozzle, is not defective if some gas passes through with the spring tension released. If the outlet is closed it may be readily seen that as the pressure builds up within the regulator and against the diaphragm the seat is sure to be brought up against the inlet nozzle.

In the second type of regulator no gas should come through the regulator with the spring tension released because of the fact that a spring is employed to close the seat against the nozzle and the pressure of the gas within the regulator and against the diaphragm has no effect in closing the inlet.

Fluctuations in the delivery pressure are usually caused by some part of the regulator being out of alignment, causing the diaphragm to open and close the inlet with a snap, and instead of a uniform delivery the regulator then works somewhat upon the principle of a riveting hammer. Quite often this might be overcome by taking off the spring housing and turning the spring to be sure that it is in a perfectly central position.

Regulators are really a technical device. Their proper working largely depends upon the care given them. They should not be carelessly handled or left in places where dirt or dust may get into the interior and be deposited on the seat or inlet nozzle, and they should never be repaired by inexperienced workmen.

Acetylene Regulators should never be interchanged with oxygen regulators because they are not designed to stand the same pressure, and because if a small quantity of acetylene gas is left in the regulator, and oxygen gas is introduced into it afterwards, a highly inflamable mixture inside the regulator is the result. Some oxygen regulators have copper or bronze diaphragms and these metals are not suitable for use with acetylene because the acetylene gas cannot fail to damage copper or copper alloys.

Before attaching a regulator to a tank, the tank valve should be "cracked." That is, opened and closed quickly to blow out any dirt or foreign particles which may be lodged there. If this is not done, foreign matter may be carried into the regulator seat and cause "creeping" or may close up some small passage along the line which will impair the working of the apparatus.

If the seat or the diaphragm of the regulator is injured through accident or abuse, the device cannot be expected to operate properly until the broken part has been replaced by a new one.

New regulators sometimes show a tendency to vibrate when a certain pressure is reached. This is usually due to the fact that the diaphragm or springs have become seasoned between the time of manufacture and the time of putting them into service.

To correct this condition, remove the bonnet and place a thin washer of fibre or copper under the diaphragm spring. If this does not work, it is advisable to replace the diaphragm with a new one.

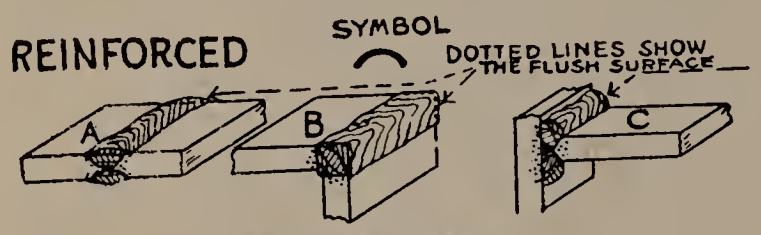
When new regulators show a tendency to leak gas, the trouble is usually due to filings or foreign matter lodging in some small crevice at the time of manufacture and being dislodged when the regulator is put in service. To get rid of this foreign matter, remove the seat, rap the body of the generator with a hammer gently, then blow it out thoroughly and re-assemble.

Regulator Screw

That part of a pressure regulator by means of which the diaphragm spring is adjusted.

Reinforced Weld

Reinforced is a term applied to a weld when the top layer of the welding material is built up above the plane of the surrounding material as at "A" or "B", or when used for a corner as at "C". The top of final layer should project above a plane of 45 degrees to the adjoining material. This 45 degrees line is shown "dotted" in "C".



Reinforced Welds.

This type is chiefly used in a "Strength" or "Composite" kind of weld for the purpose of obtaining the maximum strength efficiency, and should be specified by the designer, together with a minimum number of layers of welding material.

"Rep"

Trade name for soldering flux and filler rods for filling scored cylinders and mending cracked water jackets. Made by Kansas City Oxygen Gas Co., 1805 Grand Ave., Kansas City, Mo.

Residuum

The accumulation of water and slacked lime in the bottom of an acetylene generator.

Ribbon Flame

A narrow, ribbon-like flame secured by using a tip having a narrow slot orifice.

"Rico"

Trade name for aluminum solder for soldering aluminum sheets, etc. Made by Richards & Co., Inc., Boston, Mass

Ridge-Welding

A slight modification of the point method in which the current is concentrated by means of a ridge across which a weld is made instead of a point. See chapter on "Electric Resistance Welding."

Rigid Method

A "skipping" process used in arc welding, to minimize expansion. See "Filling Sequence" in chapter on Electric Arc Welding, by R. E. Kinkead.

Rinker-Walter Process

Oil process for producing hydrogen. Gas oil is heated to 1200° to 1400° C. and decomposed into its chief constituents, carbon and hydrogen.

Ripple Weld

The appearance of a steel weld made with a hand torch. The metal lies in ripples, having much the same appearance as little waves on a body of water.

"Rock bestos"

Trade name for asbestos products. Made by Marlin-Rockwell Corp., New Haven, Conn.

"Rockweld"

Trade name for asbestos welding paper. Made by Servicised Products Co., 1st National Bank Bldg., Chicago, Ill.

"Roebling"

Trade name for welding wire. Made by John A. Roebling's Sons Co., Trenton, N. J. See Table of Contents, "Catalog Section."

"Rogerized"

Trade name for cast iron welding rods. Made by Excelsior Foundry Co., Belleville, Ill.

"Rolasco"

Trade name for cast iron solder. Made in granulated and stick form and includes flux. Made by the Rohde Laboratory, 17 Madison Ave., New York, N. Y.

"Rol-Man"

Trade name for manganese steel welding rods for gas and electric welding. Made by Manganese Steel Forge Co., Land Title Bldg., Philadelphia, Pa. See Table of Contents, Catalog Section.

"Round File"

Trade name for gas lighters. Made by Superior Oxy-Acetylene Machine Co., Hamilton, Ohio.

"Ruby"

Trade name for copper welding flux. Made by Torchweld Equipment Company, Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Russ"

Trade name for oxygen and acetylene regulators. Made by Russ Mfg. Co., Cleveland, Ohio.

—S—

Safety Devices
For safety devices for oxygen pipe lines see "Manifolds."

Safety Disc
A device used to guard against excessive pressure or heat. Usually a sheet brass disc, used in combination with a fusible alloy.

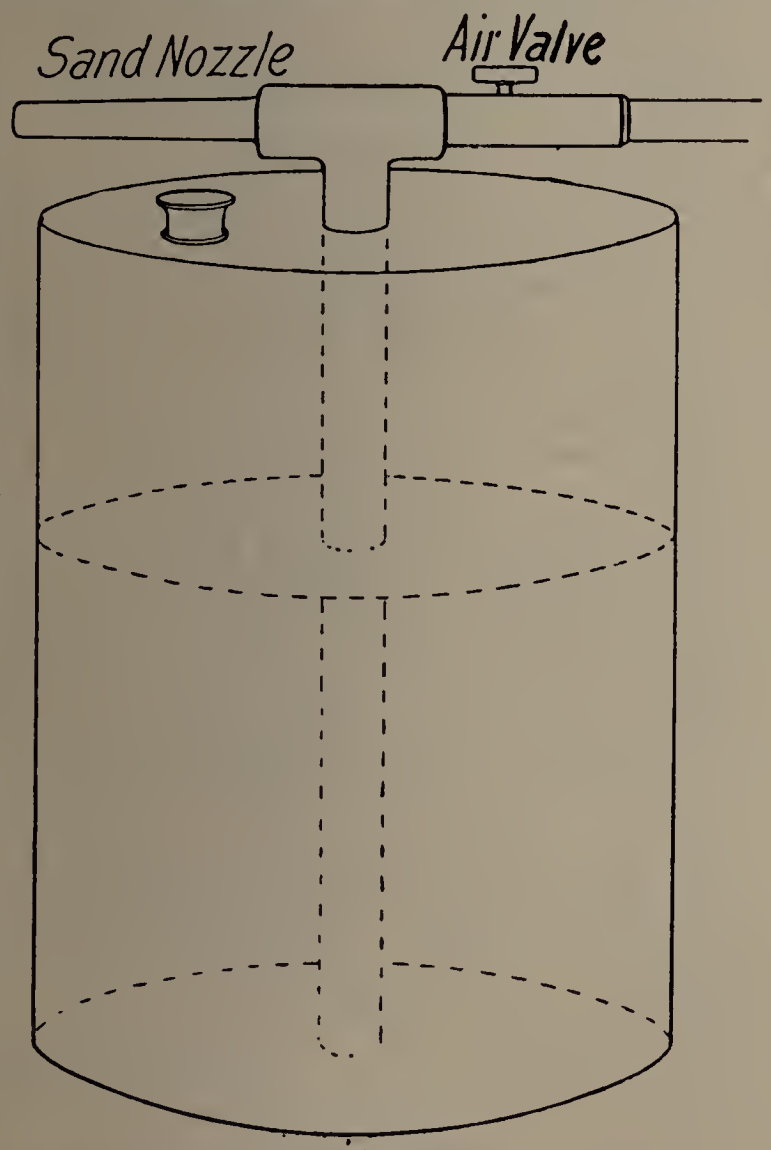
Safety Rules
See section relating to Laws, Underwriters' Laboratories Specifications, and also "Care of Equipment."

Safety Valves
A device installed in pipe systems and intended to blow out when the pressure rises above a predetermined point.

"Sallweld"
Trade name for asbestos welding paper. Made by Sall Mountain Co., 140 S. Dearborn St., Chicago, Ill.

Sand Blast
A method of cleansing fractured surfaces preparatory to welding. Fine sand under pressure is used.

The most useful tool for cleaning rust, sand and scale from parts to be welded. Wherever more than one layer of metal is to be deposited the oxide and scale should be removed from each layer before applying the next. The sand blast is probably the fastest and most efficient device for producing a thorough cleaning job. A portable sand blast consists of a heavy sheet



Sand Blast.

metal tank provided with a filling hole and an air-operated syphon. A syphon consists simply of a sand pipe extending to the bottom of the tank, a pipe tee, an air nozzle and a sand nozzle. The sand nozzle tip should be renewable and the air blast should of course be controlled by a valve near the pipe tee. A sand blast of this type will operate well with an air pressure of about 90 pounds.

Sand Holes
Craters or porous holes in castings.

Sandberg (In Situ) Rail Hardening Process
An interesting application of the oxy-acetylene flame. Consists of heating rails already in service, with the torch and then quenching with water. In one experiment, rails treated by this process, after 360,000 cars had passed over, remained unaffected, although subjected to precisely the same influence which caused adjoining lengths of untreated rails to corrugate.

Scale
A term sometimes applied to the coating of oxide on molten iron or steel.

Scaling Powder
A flux used to dissolve oxide which forms in cast iron welding.

Scarf
The chamfered surface of a joint.

Schools, Welding

CALIFORNIA

Manual Arts High School, 42nd and Vermont Ave., Los Angeles; day and night courses; oxy-acetylene welding and brazing.

Polytechnic Evening High School, W. Washington and S. Hope Sts., Los Angeles; night course; oxy-acetylene welding and brazing and theory of electric welding; all metals; 80 weeks, 240 lessons; 50% shop work, 50% lectures; tuition fee, $33.00.

Y. M. C. A. Trade School, 2834 Whittier Blvd., Los Angeles; day and night courses; oxy-acetylene welding and brazing; all metals; day course 3 weeks, night course 8 weeks, 16 lessons; 80% shop work, 20% lectures; tuition, $50.00.

Oakland Auto and Trade Schools, 211 12th St., Oakland; day and night courses; oxy-acetylene welding and brazing; all metals; 6 weeks, 30 lessons; 75% shop work; 25% lectures; tuition, $65.00.

Curtis & Geer, 507 Chestnut St., Oakland; day and night courses; oxy-acetylene welding and brazing and electric welding; all metals; 100 hours, ½ hour per lesson devoted to lecture, shop work depends on pupil's ability; tuition, $50.00.

ILLINOIS

Greer School of Automotive Engineering, 2024 So. Wabash Ave., Chicago; day and night courses; oxy-acetylene welding and brazing; all metals; 1 week of day work and three weeks of night work; full time devoted to shop work, individual lectures each time pupil learns a new metal; tuition, $50.00.

K. C. Evening School, 26th St. and Wabash Ave., Chicago; evening course, continuation school; oxy-acetylene welding and brazing; all metals; 24 weeks, 48 lessons; very little time devoted to lectures, and about 33% devoted to actual shop work; no tuition.

INDIANA

Knights of Columbus Ex-Service Men's Free Evening School, Fort Wayne; night courses; oxy-acetylene welding and brazing; all metals; 12 weeks, 24 lessons; 15% lectures and 85% shop work; no tuition.

Y. M. C. A. Night School, Indianapolis; night courses; oxy-acetylene welding and brazing, also ten hours of electric welding instruction; all metals; 12 weeks, 24 lessons; 75% shop work, 25% lectures; tuition, $40.00.

Knights of Columbus Evening School, 113 East Maryland St., Indianapolis; night courses; oxy-acetylene welding and brazing; all metals; 12 weeks, 24 lessons of 2 hours each; 75% shop work, 25% lectures; tuition free to service men and 50 cents an hour to others.

Purdue University, LaFayette; day courses; oxy-acetylene welding and brazing; 2 weeks, 4 lessons; 12 weeks' course in Forging; all metals; lectures given during shop work; tuition, laboratory fee.

KANSAS

Bartlett Auto School, 119-121 N. Topeka Ave., Wichita; day courses; oxy-acetylene welding and brazing; all metals; 6 weeks; 90% shop work; 10% lectures; tuition, $75.00.

KENTUCKY

Y. M. C. A. Welding School, 3rd and Broadway, Louisville; night courses; oxy-acetylene welding and brazing; all metals; 8 weeks, 24 lessons; 60% shop work, lectures in form of individual instruction; tuition $55.00, enrollment fee $2.00, text $2.00, materials and equipment charges $38.00, total $97.00.

MASSACHUSETTS

Northeastern Automotive School, 288 St. Botolph St., Boston; day and night courses; oxy-acetylene welding and brazing; all metals; 4 weeks; 30% lectures, 70% shop work; tuition, $30.00 per month.

MICHIGAN

Flint Institute of Technology, Saginaw and Second Avenue, Flint; day and night courses; oxy-acetylene welding and brazing; all metals; 12 weeks, 24 lessons; 90% shop work, 10% lectures; tuition, $25.00.

Michigan State Auto School, 3729 Woodward Ave., Detroit, Mich.; day and night courses; oxy-acetylene welding and brazing and electric welding; all metals; three or four weeks, thirty lessons; tuition fee, $75.00.

MINNESOTA

University of Southern Minnesota, Austin; day courses; oxy-acetylene welding and brazing; all metals; can be taken an unlimited number of weeks; 5 hours a day to shop work and 1 hour a day to lecture; tuition, $50.00.

Minneapolis Auto and Tractor School, 226 2nd St., Minneapolis; day courses; oxy-acetylene welding and brazing; all metals; 4 weeks, 25 lessons; 75% shop work, 25% lectures; tuition, $75.00.

The Motor Institute Incorporated, 2628 University Ave., Minneapolis; day and night courses; oxy-acetylene welding and brazing and electric welding; all metals; 4 weeks, 20-24 lessons; 80% shop work, 20% lectures; tuition, $75.00.

The William Hood Dunwoody Industrial Institute, 818 Superior Blvd., Minneapolis; night courses; oxy-acetylene welding and brazing; all metals; 25 weeks, 25 four-hour lessons; 75% shop work, 25% lectures; tuition, $15.00 a year.

Modern Auto and Tractor Schools, 2512 University Ave., St. Paul; day and night courses; oxy-acetylene welding and brazing; all metals; 5-6 weeks, 6 days per week; 90% shop work, 10% lectures; tuition, $100.00.

City of St. Paul Vocational School, 14th and Robert St., St. Paul; day and night courses; oxy-acetylene welding and brazing; all metals; 16 weeks, 48 lessons; 90% shop work, 10% lectures; no tuition.

MISSOURI

Sweeney Auto and Electric School, 24th St. and Wyandotte, Kansas City; day course; oxy-acetylene welding and brazing and electric welding; all metals; 4-6 weeks; 10% lectures and 90% shop work; no tuition.

David Ranken School of Mechanical Trades, 4400 Pinne Ave., St. Louis; night courses; oxy-acetylene welding and brazing; all metals; 24 weeks, 48 lessons; 65% shop work, 35% lectures; tuition, $30.00.

Rahe Auto and Electrical School, 11th and Locust St., Kansas City; day courses; oxy-acetylene welding and brazing; all metals; 6 weeks, lessons as long as pupil wants to make them; most of the time is given to shop work; tuition, $50.00.

NEBRASKA

Lincoln Auto and Tractor School, 2415 "O" St., Lincoln; day courses; oxy-acetylene welding and brazing; all metals; 6 weeks, 16 lessons; 15% lectures, 85% shop work; tuition, $100.00.

Whittier Junior High School, Board of Education, Lincoln; day and night courses; oxy-acetylene welding and brazing; all metals; 9 weeks, 45 lessons; most all time is devoted to shop work; no tuition.

NEW YORK

Brooklyn Technical High School, Manhattan Bridge Plaza, Brooklyn; day courses; oxy-acetylene welding and brazing; all metals; 20 weeks, lessons vary with the work done; 50% lectures and 50% shop work; no tuition.

Brooklyn Engineering Institute, 1115-21 Bedford Ave., Brooklyn; night courses; oxy-acetylene welding and brazing; all metals; 5½ weeks, 11 lessons; 75% shop work, 25% lectures; tuition, $60.00.

Pratt Institute, 215 Ryerson St., Brooklyn; day and night courses; oxy-acetylene welding and brazing and electric welding; cast iron and steel; 12-20 weeks; 50% shop work and 50% lectures; no tuition.

Y. M. C. A. Institute, 45 W. Mohawk St., Buffalo; day and night courses; oxy-acetylene welding and brazing; all metals; 3 weeks days and 6 weeks nights; 12 lessons; all work in shop; tuition, $45.00.

General Electric Arc Welding School, Schenectady; day courses; electric welding; iron and steel; 10-12 weeks, 40 lessons; 80% shop work; 20% lectures; no tuition.

Stevens Institute of Technology, Brooklyn; day; electric and gas; all metals; welding incidental to shop course; 2 weeks' shop work, six hours' lectures.

D.-B. Welding Institute. Full information can be obtained from Air Reduction Sales Co., 342 Madison Ave., New York, N. Y.

NORTH DAKOTA

Hanson Tractor and Auto School, Fargo; day courses; oxy-acetylene welding and brazing; all metals; 10 weeks, 12 lessons; 65% shop work, 35% lectures; tuition, $100.00.

OHIO

Lincoln Electric Co., School of Arc Welding, E. 38th St. and Kelly Ave., Cleveland, Ohio; day course in electric arc welding: chiefly steel; about four weeks; practically all practical work; instruction aimed at teaching fundamentals; deposit of $10.00 required on tools, refunded when all tools are returned.

Rahe Auto and Tractor School, Ninth and Walnut Sts., Cincinnati; day courses; oxy-acetylene welding and brazing; all metals; 4 weeks, 40 lessons; 65% shop work, 35% lectures; tuition, $100.00.

Automotive Trade Schools, Cincinnati; day and night courses; oxy-acetylene welding and brazing; course is incidental to the automotive courses and the tuition for the welding portion of the general course is not stipulated.

Ohio State Practical Motors School, 117 W. Pearl St., Cincinnati; day and night courses; oxy-acetylene welding and brazing; all metals; 1 week, 6 lessons; all shop work but 10 hours; tuition is included in Auto course.

Ohio Mechanics Institute, Central Parkway and Walnut Sts., Cincinnati; day and night courses; oxy-acetylene welding and brazing and electric welding; mild and tool steel and cast iron; 6-8 weeks; most of time spent in shop; tuition, $15.00 per week.

Y. M. C. A. Welding School, 2200 Chester Ave., Cleveland; day and night courses; oxy-acetylene welding and brazing and electric welding; all metals; 8 weeks, 24 lessons; 85% shop work, 15% lectures; tuition, $85.00.

Y. M. C. A. Welding and Auto School, 36 South 3rd St., Columbus; night courses; oxy-acetylene welding and brazing; all metals; 6 weeks, 18 lessons; 80% shop work, 20% lectures; tuition, $45.00.

Y. M. C. A. Trade School, 26 E. Rayen Ave., Youngstown; day and night courses; oxy-acetylene welding and brazing; steel, iron and aluminum; 8 weeks, 16 lessons; all shop work; tuition, $40.00.

OKLAHOMA

Oklahoma A. & M. College, Stillwater; day courses; oxy-acetylene welding and brazing; all metals; 12 weeks, 12 lessons; 75% shop work, 25% lectures; tuition, $2.00.

Chas. F. Jones & Co., Inc., 1303 E. Admiral St., Tulsa; day and night courses; electric welding; steel and cast iron; 20-25 lessons; all work in shop; tuition, $3.00 per hour.

Oklahoma State School of Mines, Wilburton; day courses; oxy-acetylene welding and brazing and electric welding; all metals; 20 weeks, 100 lessons; about 80% shop work, 20% lectures; tuition, about $50.00.

PENNSYLVANIA

Carnegie Institute of Technology, Pittsburgh; day and night courses; oxy-acetylene welding and brazing and electric welding; all metals; 36 weeks, daily lessons; tuition, night course, $30.00; day course, $180.00.

SOUTH DAKOTA

South Dakota State Auto and Tractor School, Aberdeen; day and night courses; oxy-acetylene welding and brazing; all metals; 3 weeks, 8 lessons; 65% shop work, 35% lectures; tuition, $35.00.

South Dakota State College, Brookings; day courses; oxy-acetylene welding and brazing; all metals; 12 weeks, 60 lessons; 70% shop work, 30% lectures; tuition, about $50.00.

Chattanooga High School, Chattanooga; night and day courses; oxy-acetylene welding and brazing; all metals; 6 weeks; 30 lessons; 75% shop work; no tuition.

TENNESSEE

Southern Junior College, Coltewah; day courses; oxy-acetylene welding and brazing; all metals; 9 months of school; tuition determined later.

TEXAS

A. & M. College of Texas, College Station; day courses; oxy-acetylene welding and brazing; all metals; given in connection with a course in Auto Mechanics.

UTAH

Branch Agricultural College, Cedar City; day courses; oxy-acetylene welding and brazing; all metals; 12 weeks, 24 lessons; 80% shop work, 20% lectures; tuition, $4.00.

Utah Agricultural College, Logan; day courses; oxy-acetylene welding and brazing and electric welding; all metals; 12 weeks; 65% shop work, 35% lectures; tuition, $60.00.

WASHINGTON

Modern Automobile and Tractor School, 1302 W. Second St., Spokane; day class all year, night class from October 1st to June 1st; oxy-acetylene welding and brazing; all metals; 6 weeks, 6 hours per day; 85% shop work, 15% lectures; tuition, $75.00.

WEST VIRGINIA

Wheeling Public Schools, Wheeling; day and night courses; oxy-acetylene welding and brazing; all metals; 20 weeks, 60 lessons; 75% shop work, 25% lectures; tuition, $10.00.

WISCONSIN

Stout Institute, Menominee; day courses; oxy-acetylene welding and brazing; all metals; 18 weeks, 20 lessons: 40% practical work, 5% lectures; tuition, $5.50 per quarter.

Milwaukee Vocational School, 7th and Prairie Sts., Milwaukee; night courses; oxy-acetylene welding and brazing; all metals; 18 weeks, 36 lessons; almost all shop work; tuition $1.00 registration, $25.00 deposit, $15.00 of which is returned providing the student attends 75% of the time.

CANADA

Hemphill's Trade Schools, Ltd., 228 9th Ave., East Calgary, Alta.; day and night courses; oxy-acetylene welding and brazing; all metals; 4-5 weeks; 65% shop work, 35% lectures; tuition, $60.00.

The Montreal Technical School, 70 Sherbrooke St., West, Montreal; night courses; oxy-acetylene welding and brazing; all metals; 20 weeks, 40 lessons; 75% shop work, 25% lectures; tuition, $40.00.

BRITISH ISLES

Technical College, Cardiff.
Central Technical School, Leeds.
Municipal Technical School, Liverpool.
Borough Polytechnic Institute, London.
Northampton Polytechnic Institute, London.
Municipal College of Technology, Manchester.

Screen
A device to prevent foreign matter from entering the regulator or torch, usually constructed of a fine mesh wire cloth.

"Seaco"
Trade name for Swedish Welding Wire. Distributed by Stulz-Sickles Co., 121 Lafayette St., Newark, N. J.

Seam
The line of the weld, or the edges of the metal joined.

"Seamweld"
Trade name for automatic A. C. arc welding machinery. Formerly made by Fred Pabst C., 917 Chestnut St., Milwaukee, Wis. Now made by Gibb Instrument Co., Bay City, Mich. See Table of Contents, Catalog Section.

Seam Welding
Welding a longitudinal (lengthwise) seam in sheet metal either by abutting or overlapping. This has been done extensively by special machinery embodying the oxy-acetylene flame but has not reached a high degree of perfection as in electric process. Some manufacturers of metal tubing have developed an efficient and economical method of brazing these seams. The selection of the most desirable process depends chiefly upon the purpose for which the tubing is to be used. Generally speaking, it will be found that where a strong and sound weld is necessary a slower welding process will have to be used, while for tubes which are not subject to severe strain or pressure there are several methods of rapidly and economically welding the seam. See "Line Welding" in chapter on "Electric Resistance Welding."

"Searchlight"
Trade name for acetylene cylinders and oxy-acetylene torches. Made by Air Reduction Sales Company, 342 Madison Ave., New York City. See Table of Contents, Catalog Section.

Seat
The surface upon which a valve disc rests when fully closed.

Semisteel
Name sometimes used for a metal produced by melting scrap iron with pig iron.

"Seneca"
Trade name for a. c. arc welder. Made by The Seneca Electric Arc Welder Co., Seneca, Kansas.

Setting Up Apparatus
See chapter on "Oxy-Acetylene Welding."

Shafts
Prepare for welding by beveling to a 90-degree included angle on two sides, i. e., a Double-V design. (See "Design of Weld.") Leave the edges rather blunt to assist in preserving alignment. Set up on V-blocks and weld the broken ends together first, then melt down sides of bevel to get welding started at bottom. Weld about one-third the way up on one side, then turn and weld the other side; turn again and finish welding first side; complete the weld on second side. If the break has deformed the shaft so badly that good alignment cannot be secured in the above manner, it may save time to cut away the break entirely and weld in a new piece, especially if the break occurs near the end of the shaft.

Shape Welding
By the use of a mould or dam lugs, gear teeth, low spots, etc., may be built up. See "Carbon," "Mould Welding," etc.

"Shawinigan"
Trade name for carbide. Made by Shawmigan Products Corporation, 160 5th Ave., New York, N. Y.

Sheet Aluminium
One of the most common applications of oxy-acetylene welding to sheet aluminum is found in the construction of aluminum bodies for automobiles. Various sections of the body are pressed or hammered to the required shape, then the sections assembled by welding, so that the finished body is one solid piece of aluminum. In many operations of this sort, the edges of the sheets to be welded are turned at right angles or to a height of 1½ to two times the thick-

ness of the metal. After applying a flux to cause the metal to flow freely, these upturned edges are brought together and held with clamp tongs while the short section of a few inches is welded. This welded section is allowed to cool thoroughly before removing the clamps. The tongs are then moved a few inches along the line of the weld, and the metal welded into that point. This is continued until the entire section has been joined.

Work of this nature always requires the construction of jigs which will hold the parts steadily in place throughout the operation. One body manufacturer experienced a great deal of difficulty in this particular kind of work, because no matter how carefully the welds were made, there were failures when the bodies went into service. A careful investigation showed that the cause of the trouble was that the weld was being ground off too much by the finishers. To avoid this, new jigs were constructed which permitted making the weld on the inside. After this change was made, all the welded joints gave perfect satisfaction.

Another popular procedure is to prepare the parts for a plain butt joint without any flanging, using a narrow strip of the stock to be welded for filler rod. Just before starting to weld, the end of the filler rod is heated up a bit with the flame and then plunged into a powdered sheet aluminum flux. The rod is then held in an upright position which allows the melting flux to flow along its side and coat the rod for perhaps 8 or 10 inches. This allows the welder to make a fairly long continuous weld. Some welders prefer to dissolve the flux in water and coat the filler rod and the joints with the flux solution.

It is especially important on production work of this nature to use the highest grade of flux which can be obtained. A low grade flux will interfere seriously with the speed of welding, and will also be the cause of numerous imperfections which have to be gone over again with the torch. Where the right kind of flux is used, and the welder handles his flame properly, the result is a strong smooth weld which needs only to be bumped down and buffed to get a perfect finishing surface.

After welding, all the remaining flux should be removed from the line of the weld with a wet cloth. Some fluxes are apt to cause corrosion of the metal if they are not removed in this manner.

Care should be taken not to trap the flux in the weld, in which case no amount of scrubbing would remove it. By trapping the weld, it is meant the flowing together of the metal in the joints above and below the flux, so that the flux cannot be entirely burned out.

See instructions for welding aluminum in the chapter on Oxy-Acetylene Welding.

Sheet Metal Welding*

That the introduction of oxy-acetylene welding in the sheet metal field is responsible for some of the most radical and important improvements made, is acknowledged by the leading manufacturers in this and other countries; some employing as high as seventy-five operators welding continuously.

This is especially true with respect to the manufacture of sheet steel equipment, notably doors, window sash, steel railroad cars, automobile bodies, tanks, etc.

A foremost difficulty encountered by the pioneer manufacturers was the absence of a known economical and practical method for making reliable joint connections between the various sections. They had recourse only to the old methods of riveting, seaming, splicing, soldering, etc., none of which gave the required strength and economy of production.

Because of the lightness of the material, and the abuse to which it was subjected, it was frequently found that these joints would not stand up, often owing to reinforcing plates underneath coming loose.

All this has been eliminated by oxy-acetylene welding, which has made possible the welding together of almost any type of sheet steel construction, making practically one piece. Before this advent, this result could only be obtained by various deep drawing methods, which were very expensive, making it practical only for certain classes of work.

Furthermore, manufacturing sheet metal products by the oxy-acetylene method produces far more satisfactory results than are possible by riveting or other means, as the finished product is not only stronger and more uniform, but the joints are air and liquid tight. Naturally as this new, highly efficient process was adopted, problems arose that required considerable experimenting and study.

Two of the principal ones were, to eliminate buckles, and distortion of shape.

This has been found to be best accomplished by the use of suitable jigs and clamping arrangements, together with allowances being made for the expansion of the metal.

Restricted expansion may be likened unto "an irresistible force moving against an immovable body." In welding light sheet metal, as the metal under the flame becomes heated, it expands, requiring more space. If this space is denied by the outer or cold metal, the expanding metal will take the easiest course.

Owing to its ductility, it will either rise or fall, forming a buckle. The greater the surface heated, together with intensity of heat, the greater the buckles. On the other hand, if this heat is confined to a small space and welding edges are parallel, upon welding a short distance the edges will spread, after which it will be noticed they commence to creep or overlap, as this is an easy avenue of escape. In the welding of light gage sheets, if sheets are clamped down tight upon a table to offset this difficulty, as weld cools it will crack, owing to restriction of the metal as it contracts.

In accordance with the laws of metallurgy, metal when heated expands; therefore provision must be made to take care of the expansion before welding is started where this is possible.

The welding together of large sheets of light gage metal should never be attempted without suitable equipment. For manufacturing work a large cast iron plate about 5 inches thick is used, having slots one inch

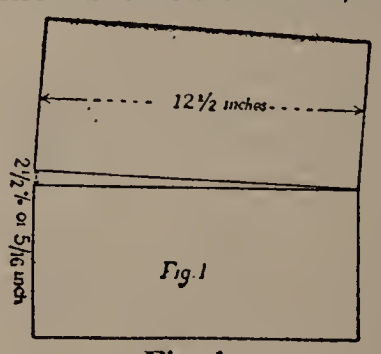


Fig. 1.

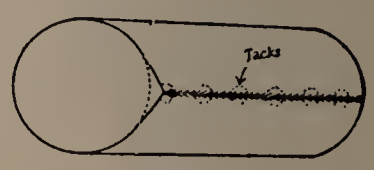


Fig. 2.

square machined in top, the entire length of casting. The edges are then placed over slot, which provides air space and eliminates undue conduction.

Bars approximately 1 inch by 5 inches by length of weld are placed on each sheet, allowing a space of about one and a half inches for tip manipulation.

This confines the heat to such a small space that the rigidity of the weld holds the metal firm upon heating and cooling.

An overhead arrangement employing adjustable arms is then brought into play to hold bars securely. The bars should never

Written by J. B. Diehl for The Welding Engineer.

be clamped down tight, as their mission is only to hold sheets firm on table and to minimize heated surface.

In the jobbing shop this class of work can be handled successfully by the use of two I beams placed parallel to each other with a space of one inch between. Bars are then placed on top of sheets and clamped into position with C clamps.

In sheet or plate welding, the proper judgment of alignment preceding the operation is one of the foremost factors for success. If the space between the sheets is too small it will result in lapping, or, if they cannot rise to lap, the result will be what is known as crowding, so that buckling is inevitable. Where space allowance is too liberal, the result very frequently is unreliable welding.

It is inadvisable to weld lapped sheets for three reasons, i. e., poor appearance, altering dimensions and unreliable welds which is the same as not melting through a butt weld, always leaving a possible chance to start the seam again. This is especially objectionable in the welding of parts subjected to pressure.

To overcome this difficulty, allowance should be made for the expansion and contraction of the metal largely depending upon size, thickness, heat applied and speed of welding. For general work, the sheets are placed in position as in sketch No. 1, in which the opening allowed at farther end of sheets is 2½% of total length of weld. Some instances require as much as 6% allowance, depending upon whether the welding operation is to be continuous or not.

Where welding is alternating, a greater allowance must be made to offset effects of shrinkage as weld becomes set, as this prevents the edges from resuming their previous position. See scale of allowances.

After welding is started, if edges close too quickly a wedge may be forced into opening restricting this action considerably; although this is liable to cause distortion if allowed to go too far. When edges do not close quickly enough, heating the edges to be welded will often bring the desired results, after which they are tacked.

On some classes of work, owing to its shape, these methods are not practical, therefore we must resort to tacking, or welding edges together in spots every few inches preliminary to the main welding operation. After tacking, the seam is straightened, this being essential for good welding. This system, however, is likely to cause distortion (see sketch No. 2), as expansion cannot act laterally, although this can be removed by drawing with the hammer.

Flanging, another system of merit, gives very good results on certain classes of work. This is accomplished by bending the edges of the metal up at right angles to the sheet about ⅛ inch. Upon bending these edges, the metal at the base of the flange will be stretched; therefore, as heat is applied to the flange, a considerable portion of the expansion is taken care of. An excellent feature of the flanging system is the elimination of the filler wire, it being only necessary to melt flange edges together.

Cast iron forms under the metal are used in welding difficult shapes, while a slotted casting is clamped over joint. These slotted castings may be used on short flat, as well as irregular work, being casted to meet requirements at a small cost. See sketch No. 3.

As some work coming from the presses does not conform with the shape of these castings, asbestos sheet is placed between the sheet metal and top casting filling in all irregularities.

When a fine finish is required, best results can be obtained by making the weld on inside whenever practical to do so, as less time is required in finishing and added metal remaining on inside gives a stronger joint. Care must be exercised to melt metal through, otherwise a good finish cannot be obtained.

In the jobbing shop where the owner does not find it advisable to have these forms, he must resort to laying wet asbestos or other cooling mediums on each side of the seam to check the heat. As this does not always give the desired results, the welder should have some knowledge of removing the ensuing buckles. This knowledge will often help to remove the buckle problem entirely.

A buckle is simply more metal in a given space than belongs there. By trying to pound this down we do more harm than good, i. e., pushing the metal from the center toward the outer resisting metal. As this is the expansion problem all over again, the result is greater buckling.

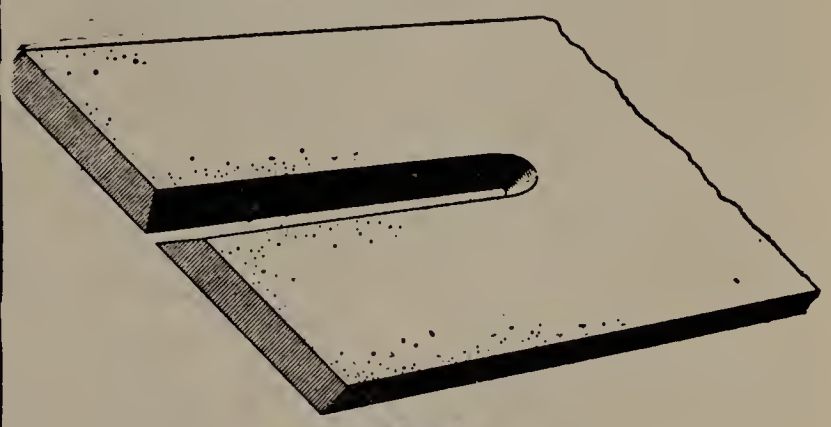


Fig. 3.

To remove a buckle, a sheet metal worker's block or any shaped piece of smooth metal should be held underneath, or if large sheets, they can be placed upon a table. A wooden mallet or a coppersmith's hammer is used for the drawing process, exercising care that the metal is not stretched unduly.

Handle is held parallel to plane of the work, blows should be light and struck squarely on the metal, otherwise the metal would show hammer marks.

Assuming the buckle covers a space of a two-inch circle, we would start about one inch outside of this. In bringing the tool down on the metal it is drawn toward the workman, drawing the metal away from the buckle as shown in sketch No. 4, completing a circle around the buckle.

If metal is not then drawn taut, complete

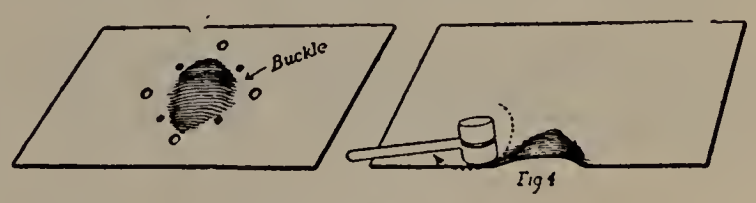


Fig. 4.

another circle inside of this, using about four blows, according to size of buckle, until it disappears, the idea being to bring the inner metal out to take the place of that just drawn out. However, the outer metal must always be drawn first to allow for this action.

Where several are to be considered in close proximity, the outer ones must be eliminated first.

Where considerable job work is done, a handy contraption for shaping sheet metal can be made with sand encased in leather, which is sewed around the edges.

On hollow parts, as with pressed steel doors, etc., the block cannot be used; therefore, the oxy-acetylene flame plays an important part. In welding this class of work a channel iron of ⅛ metal is spot welded inside of panel at the joint. Upon clamping the slotted casting over the joint, this support greatly diminishes the tendency of the metal to sag. However, there are nu-

merous instances where hollow shapes cannot be treated this way; therefore the chance of buckles is greater. Removing them on light work requires the use of a small tip, used in conjunction with water. Start should be made about one inch outside of buckle, holding the torch with the small white cone touching the metal until a spot appears dark, cherry red, resulting in the expansion of this part, care being taken not to melt the metal. Torch is quickly withdrawn, and spot quenched with water to stop contraction. About four spots of this nature encircling the buckle will cause the surplus metal to be mostly distributed. A few light taps with the hammer as described above will remove the buckle entirely. The thickness of metal and size of buckle must always be taken into consideration and worked accordingly.

When applying flame, care must be taken not to allow too much heat to radiate into buckle, as this would conflict with the purpose of the process. Flame should be pointed away from buckle and worked very quickly.

These methods apply to plate work as well as light gage metal, allowances to be made for different sizes.

A great many of the larger sheet metal shops use spring power or trip hammers for removing buckles, these being very speedy and efficient. By this method the work is moved around under the hammer, whereas the hand operation is completed by moving the hammer over the metal. Both instances are worked on the same principle.

The manipulation of the torch being an important factor in the welding of plate and sheet metal, several of the best methods are herewith described. The ones in general use are: The oscillating motion for heavy work; circulating motion for medium work; the Swish weld, which can be used on medium work and for finishing on heavy metal; and the Fade-a-Way weld for light work, this being probably the fastest method known, comparing favorably with machine welding. On heavy work the wire hand should be given a circular motion to puddle the metal well.

On some classes of medium work the rippled effect resulting from the circular movement is not desired; therefore the Swish weld is substituted, making a smooth weld that is more easily finished off if welded properly.

The Swish weld is completed by holding the tip almost vertical to the plane of the weld, with handle at right angle to same, although on heavier work it is often more

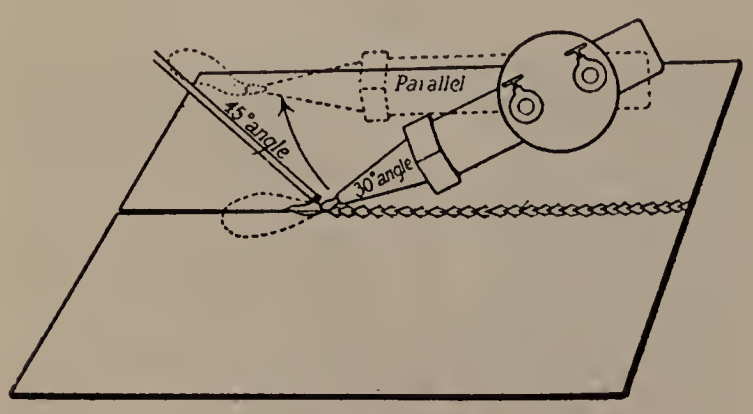


Fig. 5.

advantageous to work in line with the weld. When edges of the metal arrive at the melting point, wire is held before the small cone; as the fusion point is attained the torch is brought forward by a sharp movement of the hand.

This action places the drop and swishes the molten metal ahead, leaving a comparatively smooth path. As the operator learns to melt the edges and wire simultaneously, following up with the swish movement, he will find it very easy to make a neat, rapid weld with less ripples than by any other method.

This system is also used extensively in finishing boiler welds, and many others that do not require grinding or filing.

The fade-away weld, which requires considerable practice to be done correctly, may easily be understood by referring to sketch and instructions.

Head of blowpipe should be inclined with the tip at a 30-degree angle to plane of weld to secure fullest benefit of the secondary preheating flame, which is essential for speed welding, handle being at right angle to the seam.

The small cone is allowed to touch the metal. while the feed wire is held directly before the cone. As edges of the metal melt, the wire held at a 45-degree angle is brought under the cone, melting instantaneously, fusing edges and wire together.

To describe the movement of the torch hand, we may say that the hand and forearm is given an eccentric motion. As the edges melt, the wire hand is brought forward toward the torch, as described above. The hand is then turned, raising the tip from the 30-degree angle until it is parallel with weld.

To secure speed and neat workmanship by this method, it is absolutely necessary to get the correct movement of the hands. In an effort to make these movements plainer, we might say: when edges are ready to melt, and the wire brought toward the torch under cone, the torch is brought forward with an upward turn, taking a drop of the wire and placing it as shown in sketch with a herring-bone effect that is pleasing to the eye.

As the torch moves forward on the upward turn, placing the metal, the wire hand is moved backwards. As the torch goes down—or backwards, the wire is brought forward continuously administering these drops.

By using the correct size tip and wire, together with a properly prepared job, this action is continuous, making a neat, narrow weld, the speed of performance depending upon the skill of the operator.

Scale of Allowances

2%=¼-inch opening for every 12½ inches length.

2½%=$\frac{5}{16}$-inch opening for every 12½ inches length.

3%=⅜-inch opening for every 12½ inches length.

3½%=$\frac{7}{16}$-inch opening for every 12½ inches length.

4%=½-inch opening for every 12½ inches length.

4½%=$\frac{9}{16}$-inch opening for every 12½ inches length.

5%=⅝-inch opening for every 12½ inches length.

5½%=$\frac{11}{16}$-inch opening for every 12½ inches length.

6%=¾-inch opening for every 12½ inches length.

Upon melting through the metal, the upward turn of the torch brings the molten metal up and forward, that would otherwise form a projection underneath the weld. This effect could better be called an overlapping pear-shape, as is obtained in lead burning.

Welding Thin Sheets

In case of thin sheet metal and other thin pieces, it has been explained that the time of operation can be reduced considerably if the edges are flanged as shown in

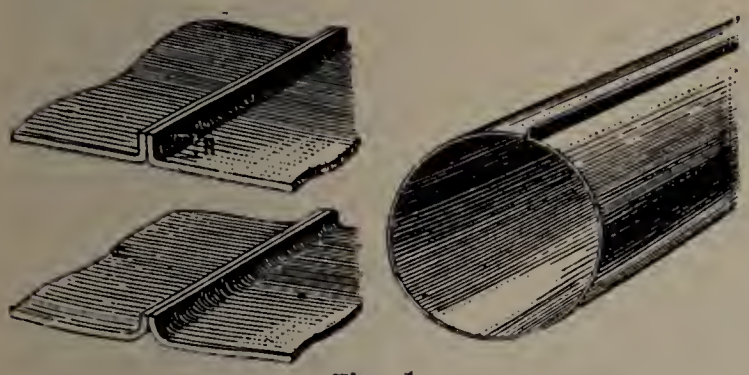


Fig. 1.

Fig. 6. Fig. 7 shows how small clamps can be used to hold these flanged edges together while they are being tacked with a torch flame, and Fig. 8 shows the correct position of the torch for completing a weld. It is

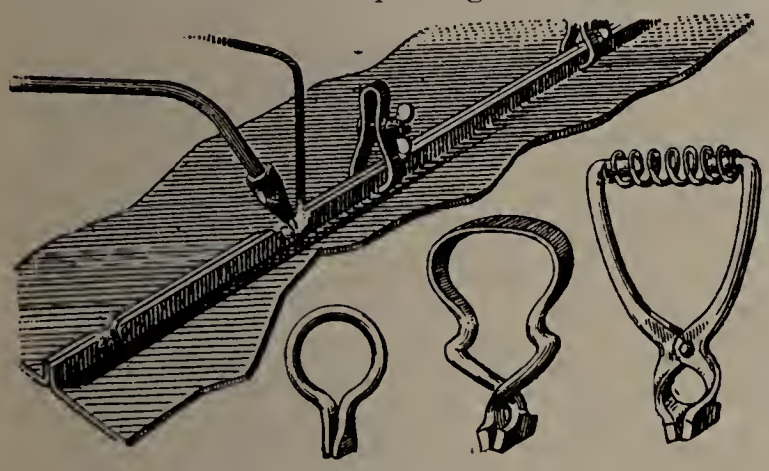


Fig. 2.

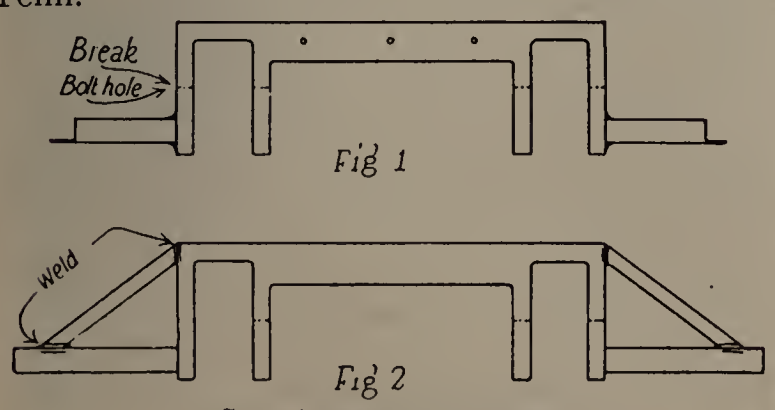
not necessary to use a filler rod except in cases where a flux is necessary when a rod can be used for applying the flux, or it may be dissolved and applied with a brush. As shown in Fig. 8, the angle of the torch

Fig. 3.

should be about 35°. If the end of the cone is placed too high, the edges will not weld except on top, and although the top part of the weld will look well, perfect penetration will not be secured. The joint will not be solid and will probably show a crack on the reverse side.

"Shoot-A-Lite"

Trade name for gas lighters. Distributed by American Lava Corporation, Chattanooga, Tenn.



Street Car Side Frame.

Side Frames of Street Car

One of the most troublesome jobs that come through, as shown in Fig. 1, and any amount of reinforcement makes it unsightly. To overcome this difficulty and prevent future breaks these frames are welded with the electric arc and reinforcement braces are added. The brace does not mar the appearance of the truck side, but gives it the appearance of a bridge truss, as shown in Fig. 2.

Side Seam

The horizontal seam of an upright section.

"Siemund"

Trade name for generating equipment for arc welding, and for welding wire. Made by Siemund Wenzel Electric Welding Co., 81 Hancock St., Long Island City, New York.

Silicon

A metallic element. Its presence in iron and steel increases brittleness and resistance to abrasive wear.

Silver Soldering

A process used for small parts requiring strength in the union. Silver solder is a hard solder which consists of silver, copper, zinc or brass, the exact composition depending upon the nature of the work. Jewelers, for instance, use a composition consisting of 70 parts silver and 30 parts copper. Powdered boracic acid or borax may be used as a flux.

"Silva"

Trade name for a solder for all non-ferrous copper alloys, except low degree brass. Made by The Rolide Laboratory, 17 Madison Ave., New York, N. Y.

"Simplex"

Trade name for special type of metallic arc welded rail-joint. Made by Indianapolis Switch and Frog Co., Springfield, Ohio.

Single Operation Outfit

A generator or motor-generator, regulating type which will provide current for only one welding circuit at a time. See "Multiple Operator Outfit."

"Six-in-One"

Trade name for all-purpose goggles. Made by Bastian-Blessing Co., LaSalle St. and Austin Ave., Chicago, Ill. See Table of Contents, Catalog Section.

Slag

Impurities forming in the molten bath on the line of the weld. When not removed the weld suffers. This term is also applied to the scale blown out of the kerf when cutting with the torch.

Slag-Covered Electrode

Used in metallic electrode arc welding. The electrode is heavily coated with slag which covers the weld and cools in the form of a brittle mass that can be chipped off when the weld is completed.

Slag Inclusions

See under "Kish."

Slavianof

An electric arc welding process. A metallic electrode is used in place of the carbon electrode of the Bernados process. It is commonly known as the metallic arc welding process. See chapter on "Electric Arc Welding."

Sludge

A term often applied to the accumulation of slacked carbide and water in the bottom of an acetylene generator.

"Smith-Fire"

Trade name for fluxes. Made by Morey Flux & Chemical Co. See Table of Contents, Catalog Section.

"Smith's"

Trade name for welding and cutting torches, accessories and supplies, pre-heating torches, acetylene generators, etc. Made by Smith's Inventions, Inc., Minneapolis, Minn. See Table of Contents, Catalog Section.

"Smock"
Trade name for a kerosene preheating torch. Made by H. A. Smock, 439 Mass Ave., Indianapolis, Ind.

Sodium Hydroxide (NaOH)
Carbonate of soda (soda ash).

"Sod-Loom"
Trade name for an aluminum solder. Made by The Ever-Stay Metal Co., 1501 Jackson St., Omaha, Neb.

Soft Solder
An alloy which varies in composition, but is used for soft soldering. Such an alloy usually consists of lead and tin, chiefly, other metals being added to lower the melting point. Soft solders are usually known by the terms "common," "medium," and "fine," depending upon the tin content. Solders containing the most lead are cheapest and have the highest melting temperatures. "Fine" solder is best for soldering brass and tin-plate, cast iron, steel, copper and other alloys. "Common" solder is used largely by plumbers and this solder contains two parts of lead to one of tin. The composition used for solder must have a lower melting point than the metals to be joined. It should be remembered, however, that if the soldering metal fuses almost at the moment the joined edges fuse a better joint will result.

"Soft Y Weld"
Trade name for a flux made by The Black Rock Mineral Co., Denver, Col.

Solder
An alloy which varies in composition, but which consists usually of metals fusing at a comparatively low temperature. See "Silver Soldering." "Soft Solder," etc. Solders are most generally referred to as being "hard" or "soft." The soldering process is used where strength is not necessarily a factor, but where tight seams are desired.

SOLDERING AND SOLDERS

Soldering consists in using fusible alloys for joining metals, the kind of solder used depending on the metals to be joined. They are distinguished by the following names: Hard, soft, silver, gold, aluminum, copper, tin, pewter, spelter, etc. In all cases the solder used should be more fusible than the metals to be joined.

Hard solders are called spelter and hard soldering is called brazing, and this process of soldering gives greater strength than in the use of soft solder. Hard solders will also stand more heat than soft solder. They contain metals such as copper, zinc, silver, etc., and require a red heat to melt them.

Soft solders are made of lead, tin, bismuth, etc., and are used where the articles to be joined must be made air or water tight, and are not exposed to high temperature. It is a much simpler operation to join metals by use of soft solder than hard solder, and this method is used where possible in place of brazing.

The ordinary good grade of solder is made of tin and lead in equal parts. Fine solder: tin, two parts; lead, one part. Cheap solder: tin, one part; lead, two parts.

Tin	Lead	Melting Point
1	3	250°
1	2	227°
1	1	188°
1½	1	168°
2	1	171°

By varying the proportions and adding bismuth, a solder may be made that will melt in boiling water.

Bismuth Solders

Tin	Lead	Bismuth	Melting Point
3	5	3	94.4C
1	1	2	96.1
1	2	2	112.8
2	1	2	113.3
1	1	1	123.3
2	2	1	143.5
3	3	1	154.4
4	4	1	160.0

These mixtures are used in different ways, such as operating an electric alarm when a certain temperature is reached, opening sprinkling heads, etc.

In mixing solders, the least fusible metal should be melted first and the more easily fusible metals added. Mixing soft solders should be done under melted tallow and agitated by thrusting a stick of green wood or raw potato under the molten metal. The escaping steam stirs and mixes the metals very thoroughly. They can be then run out in molds; a small channel of angle iron will serve.

In mixing hard solders, they should be melted under a coating of powdered charcoal or borax. Hard solders may be reduced to granulated form (the most convenient form for use) by casting into small strips or ingots and filing with a coarse file. Silver solder should be rolled or hammered into thin strips or sheets and cut to suitable size. A silver coin hammered thin makes a very satisfactory solder for iron, copper and hard brass. Copper to which is added 10 per cent of silver is suitable for soldering sheet steel.

In the process of soldering it is necessary to heat the metals above the melting point of the solder and as metals readily oxidize when heated, a flux is necessary to coat the surfaces after they are cleaned, to prevent their oxidation. The surfaces may be cleaned by scraping or filing, or by means of suitable acid or both. In the case of sheet iron covered with scale, a suitable method is to scrape or file the surface or scratch it with a wire brush and coat it with strong muriatic (hydrochloric) acid, letting the acid act for 5 or 10 minutes and then wiping it dry and applying cut acid (hydrochloric acid to which zinc has been slowly added in excess). Cast iron may be soldered by using a flux made by adding zinc chloride to melted tallow and heated until it foams and turns a reddish brown. Zinc chloride solution also is satisfactory. It is very important, however, to clean the surface very thoroughly and solder immediately after cleaning.

For hard soldering, borax is used as a flux. For silver soldering, finely powdered borax mixed with water to the consistency of paste is very suitable. It is desirous, however, to let this flux dry after applying.

For soldering galvanized iron raw hydrochloric acid is used as a flux.

Metals to be Soldered	Flux Used
Sheet metals, copper, brass, gun metal, etc.	Zinc Chloride
Zinc, Galvanized iron	Hydrochloric acid
Copper and iron	Ammonium chloride (Sal-ammoniac)
Soft alloys and tinware	Rosin
Pewter	Venice turpentine or Gallipoli oil
Heavy lead	Russian tallow
Light lead	Palm-oil candle

When acids are used the soldered joint should be thoroughly washed to remove all excess acid and to prevent subsequent corrosion. In soldering jewelry use zinc chloride.

For soldering small pieces, tin foil cut to size and moistened with a solution of sal-ammoniac placed between the pieces to be soldered may be used. The pieces should be made flat and smooth at the joint, the tin foil inserted and the pieces gently heated.

For soldering gold articles a solder made of 2 grs. silver, 1 gr. copper, 1 pennyweight gold may be used with success. Another solder which has the color of gold is made of copper 2 grs., zinc 1 gr., gold 1 pennyweight.

A good solder for general use contains gold 18, silver 4, copper 4, copper 5, zinc 2 pts., another can be readily prepared by fusing 1 pennyweight of 18 carat gold with 5 grs. of spring brass (2 of copper, 1 of zinc). Among the jewelers' gold solders, the following may be mentioned:—1 best solder,

gold 12½, silver 4½, copper 3 parts; 2 medium solder, gold 10, silver 6, copper 4 parts; 3 common solder, gold 8½, silver 6½, copper 5 parts. (The Goldsmith's handbook.) Antimony, arsenic, tin and lead should not be used in soldering gold.

Silver soldering. Silver solder is used in many places where great strength is required, and where the article is exposed to heat. Being expensive, the solder is used very sparingly and carefully, resulting generally in neat work. Silver solders are made of a mixture of silver, copper zinc, in different proportions; a good one for joining brass, copper iron, etc., is silver 18, copper 4, zinc 1 pt. Another one of about the same quality is made by using coin silver 0, copper 2, zinc 1 part. By reducing the amount of silver a very easily melted solder can be prepared thus: Silver 6 pts., copper 2, zinc 1 part and silver 4 pts., copper 1, zinc 1.

The Silversmith's Handbook gives the following table:

Silver Solders

Remarks on use	Parts of Silver	Parts of Spring Brass	Parts of Copper	Parts of Zinc
Jewelers' Hardest	4	....	1	....
Hard	16	....	3.5	0.5
Easy	14	....	4.5	1.5
Common Hard	12.5	....	6	1.5
Common Easy	11.5	....	6.5	2
Easy for chains	10	5	....	1
For Steel	18-19	2-3	1	....
Brass, gun metal, bronze	1	1	....	....
Brass, gun metal, bronze	1	....	8	8
German silver, gun metal, bronze	3	....	2	4
German silver, gun metal, bronze	5	6	....	2
Brass, small articles	2	....	5	3
Jewelers' instrument makers, very tough and fluid	11	....	13	....

To silver solder a tube or rod into a casting or coupling, prepare the pieces by cleaning them with emery cloth or grinding. Provide a small recess into which the metal may flow. Have the pieces thoroughly clean. Apply a flux of powdered borax and water mixed to a consistency of paste and allow the paste to dry. Next heat the pieces to redness or until the solder (wire), not foil, will readily melt when placed in contact with the articles and quickly fill the groove. If small spots remain where the solder does not flow freely, slightly more heat should be applied. If the pieces are clean this is no more difficult an operation than using soft solder.

In silver soldering a band saw or other flat object, a different method must be used. The ends of the saw must be bevelled so as to make a lap joint, the bevel being as long as the width of the saw or slightly longer. They must be supported by suitable means to keep them in line while soldering, allowing a space between the supports where the heat is applied. When the saw ends are properly placed, in position, a piece of solder foil, the size of the joint, is placed between the bevelled pieces and borax is applied. A clamp made of a piece of band iron formed into a ring, is sprung apart and slipped on the joint to hold the pieces together, and held firmly until cold. The actual operation of soldering should be done in a few minutes, preferably with a city gas flame, or blow torch, or acetylene and air. The oxy-acetylene flame is too hot although if a small size tip be used and is held, some distance away, overheating can be avoided and successful results obtained. If a gasoline blow torch is used, holding a dry pine stick or piece of charcoal back of the joint while the flame is directed on it, the operation will be more rapid. It is a rather difficult matter to attempt to temper a saw after soldering and the usual course is to use it without any re-tempering.

One of the most successful processes of brazing is the "Ferrofix Brazing Process," invented by Pich. U. S. Pat. No. 688030, 647632. This is used mainly on cast iron as the brass used alloys with the iron. The brazing liquid is prepared by boiling cuprous oxide with concentrated borax solution and allowing the mass to cool down to a paste. The method of procedure is to set the pieces up on fire brick in perfect alignment, mix the fluxing powder with the brazing liquid and apply to the surfaces with a brush; heat and apply more flux until it runs through the joint. Then apply ordinary hard brass spelter with a little flux until it flows through thoroughly. Remove source of heat and continue to add spelter until the heat of the casting is insufficient to melt it.

The oxygen of the cuprous oxide combines with the carbon of the iron leaving fine copper distributed over the surfaces of the break, and producing a layer of decarbonized iron. The spelter now alloys with the copper and immediately combines with the decarbonized surfaces of the break. It is a difficult task to weld a joint that has been previously brazed by the ferrofix process as the decarbonized iron refuses to flow. In a case of this sort it is necessary to cut out the iron in the immediate vicinity of the joint and fill in with new metal.

Aluminum Bronze may be soldered with following alloy: Tin 88.5, copper 9.6, bismuth 2.5. This solder should be used with silver chloride as a flux.

The following gives the formula for a solution which is inexpensive to prepare and will be found a great improvement over the soldering acids generally used in machine shops. In addition to being an excellent soldering solution for brass, copper, tin and bronze, it may also be used as a flux for soldering galvanized iron. The union between the galvanized parts is perfect when this flux is used. The method of preparing is as follows:

Make a saturated solution of zinc chloride by dissolving as much zinc chloride as possible in water. Ammonium Chloride (ordinary sal ammoniac) is added to this, the quantity being 1/10 part by weight. The solution should be thoroughly mixed before using. A good paste for use where soldering acid would be objectionable is composed of the following ingredients: Ammonium chloride, 25 per cent; alcohol (wood or grain), 25 per cent; common vaseline, 50 per cent. The ingredients are thoroughly mixed before the paste is used.

Soldering Aluminum

There are a great many aluminum solders on the market today, and they all doubtless have their merits.

For the sake of brevity we will only quote four formulas of solders designed to solder aluminum, the first of which, if used according to directions, will give unvarying satisfaction.

(1) 61 parts block tin.
36 parts zinc.
3 parts copper.

(2) 12 parts tin.
2 parts zinc.
1 part aluminum.
1 per cent sodium chloride.

(3) 2 oz. aluminum.
2 lb. 2 oz. zinc.
1 lb. 11 oz. phosphor-tin.
5 lb. 7 oz. block tin.

(4) 5 parts tin.
3 parts zinc.
2 parts lead.

The necessary tools are a good, heavy rasp or file, a chisel to V out the crack (if it is a crack to be repaired and the metal is thick at that point) and a small half-round file (an old file will do very well, attached to a suitable handle) and a convenient source of heat.

A soldering torch, a gas and air torch; or

if nothing better can be had a gasoline blow torch may be used.

The first two above mentioned are so far superior that whenever possible one or the other should be used.

If the man who intends to do the soldering has no gas and air it is a simple matter to unstrap your lighting tank and hitch a soldering torch to it with a suitable length of hose.

The reader must not confuse a soldering torch with so-called soldering iron, as an open, clean flame must be used and a degree of heat is required far greater than any soldering iron is capable of producing.

Now for the process of soldering: We will suppose that we are to solder a crack in a transmission case.

With a sharp chisel we will V out the crack nearly through the case, being sure to leave no dirt or grease of any kind in the crack. Now with our rasp, file a space clean and bright for a half inch to an inch all around the crack; now follows the tinning operation, which is the one operation that must be done right to insure successful soldering. Tinning, as its name implies, consists of spreading a thin coat of solder over the place to be soldered in order that there may be more solder added, and have it stick.

Turning on our soldering torch until we have a good hot flame on our gas and air flame, whichever one we are using, we play the flame directly on the spot to be tinned, holding the torch just far enough back that the greenish inner cone of our flame just touches the metal.

The purpose of holding that particular part of the flame on the metal is to minimize oxidation. When the reader is told that freshly cut or scraped aluminum oxidizes quickly at ordinary temperatures and much more rapidly when heated he will readily see that the outer cone of a flame which is oxidizing must not be used or a film of oxide of aluminum will be formed that will make it almost impossible for the solderer to make his tinning stick.

After the heating has been in progress for a minute or so, taking a stick of aluminum solder in one hand, touch the part of your case under the flame gently with a slight rubbing motion. If the stick melts and coats the surface of your case the case is hot enough to start tinning. If it does not melt, continue heating until it does.

When the case is hot enough to melt the solder, smear on a little more of the solder, then lay down your stick solder and pick up your old file, grasp it firmly and start rubbing the solder that was smeared around the crack, holding your file at an angle of about 45 degrees, and rub with the outermost end of the file. Then rub, rub, rub the solder in the crack and all around it until you can just feel the solder taking hold and every bit of the filed surface is covered with a thin coat of it. It takes time and practice and elbow grease to do a good job of tinning, but when you once "catch on" it is easy.

It must be remembered that the flame must be held on the spot to be soldered during the entire tinning operation. While there is not much danger of melting your case, care should be exercised that it does not happen. The purpose of the rubbing motion in tinning is to scrape what oxide has formed during the heating operation ahead of the file, while just behind the file comes the thin coat of solder and covers the scraped place before the air has had time to attack it. The rubbing also works solder into the pores of the case.

While the tinning is still hot, melt enough more solder to fill the crack and make a neat patch, smoothing the solder out with the hot file. The solder should be plastic, but not "running hot".

If you want to make a particularly nice job, take a small, flat, smooth pine stick and smooth it up. The wood being a poor conductor of heat will not chill the metal and makes a very smooth job.

The flame should not be played on the solder while you are smoothing it up with the pine stick, as it will char it and solder will adhere to it and drag across your patch, making it rough.

When cold the solder looks very much like the aluminum and when struck with a hammer sounds very much like the rest of the case.

One need have no fear of internal strains as the heating is too slow to cause them; neither is there any danger of cracking the case, and no special precautions need be taken.

The four formulas were quoted more for information than recipes that the solderer should make up. It is best that he purchase it ready made from some reputable dealer in such supplies.

Soldering, Electric

In the manufacture of watches, jewelry, optical frames and similar work involving joints between pieces of very small cross-section a method known as electric soldering is often employed. In this process the parts are heated in a machine that is essentially the same as an electric resistance welding machine. Such a machine consists of:

1. A transformer for reducing shop current to current suitable for electric welding.
2. Clamping jaws for holding the parts in the secondary or induced current of the transformer.
3. Mechanical devices for operating jaws, controlling current, etc. In theory electric soldering is very similar to resistance welding. The secondary current from the transformer has a very low voltage and a comparatively high amperage. This current is taken away from the transformer through a thick copper conductor which offers little resistance to the flow. When it reaches the work it encounters greater resistance on account of the smaller cross section of the work, and the portions between the clamping jaws become heated. As the solder has a lower melting point than the work, it will melt when touched to the joint, though the latter has not reached the melting temperature. The advantage of this process over the use of a flame or iron for heating is that only a small part of the work is heated and the temper is not lost from it. Also the work is kept in sight and the heat easily controlled. The operation consists of:

1. Coating the work with a suitable flux (borax is used for this work a great deal).
2. Putting work in clamps.
3. Closing jaws to form joint.
4. Turning on current.
5. Touching solder to the work at the joint.
6. Turning off current.

The electric soldering process can be applied economically only in production work where the same pieces are assembled in large quantities, because each machine is limited in the range of work it will handle. The soldered joint is not, of course, as strong as a welded joint.

"Solfrunt"

Trade name for a gauge whose case is cast solid in front with a lightly retaining closure plate at the back, designed especially for use on high gases compressed to pressures approximately 2,000 lbs. Made by United States Gauge Company, 44 Beaver St., New York City. See Table of Contents, Catalog Section.

"Sorensen"

Trade name for welding rod pincers. Made by C. Sorensen, 18 E. 16th St., Chicago, Ill.

"Southwark"
Trade name for an electric flue welder. Made by the Southwark Foundry and Machine Co., Philadelphia, Pa.

Spectacles
Eye-glasses worn for protection by welders. See "Eye Protection."

Speed of Welding
All references to speed of welding have been more or less understood to be a designation of the comparative rate of travel of the electrode or filler rod without regard to the rate of deposition of metal. There is no standard unit of measurement of speed of welding. As a matter of fact no one can specify a certain speed and be sure of obtaining desired results unless the amount of current or gas is also specified.

Spelter
The material used in brazing. See "Silver Soldering," "Brazing," etc.

Spoon
A small instrument or "flatter" used in finishing the surface of an aluminum weld.

Spot Welding Electric
See chapter on "Electric Resistance Welding."

Spreading
Depositing metal by the metallic arc welding process, using a side-to-side motion while the electrode is being advanced, giving a wider deposit than is secured when laying a single bead. For good results, care should be taken not to move the electrode so fast that it cannot form a crater properly and deposit all of the electrode maertial into the crater thus formed. This method is especially recommended when slag covered electrodes are used. If spreading is done with a flux covered electrode, it is recommended that the bare side of the electrode should face the direction of the advance so that the flux covering is in the rear. The operator must hold a short arc to insure penetration because if the arc is too long the deposited metal will simply lie on top of the parent metal without taking hold. Since the forward rate of advance of an e'lectrode should be about the same as if a single bead were being made, the actual rate of depositing metal is faster; consequently, more current will be required. Spreading is recommended for joining parts which are comparatively thin.

Spreading Weld
A spreading weld is made by moving the electrode from side to side, and advancing at the same time.

"Standard"
Trade name for carbide. Made by Standard Carbide Sales Co., 15 W. 37th St., New York City.

"Star"
Trade name for oxyacetylene torches. Made by Air Reduction Sales Company, 342 Madison Ave., New York City. See Table of Contents, Catalog Section.

"Staylit"
Trade name for cutting torches. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Steel
See chapters on "Oxy Acetylene Welding," "Electric Arc Welding," "Thermit Welding," and "Heat Treatment of Steel."

Steel, Structure and Restoration of
If a piece of steel containing say 0.50 per cent carbon be suitably prepared by polishing, etc., and then examined under the microscope, it will not be found the same everywhere. If the magnifying power be not too great, what you see will appear something like a map. There will be patches divided from each other by strips or bands. In the present case, the total area occupied by the patches will be not greatly different from that occupied by the dividing bands. The bands and patches differ from each other. The bands contain no carbon; they are pure iron. All the carbon is in patches.

Now of course we have been looking at a surface. In the body of the piece of steel we should have lumps or grains instead of patches. The pure iron will fill up the spaces between the grains. What we have in the piece of steel is very similar to what we have in a piece of concrete. If we saw the concrete through and thus lay bare a section, we will see patches and bands. The patches correspond to the pieces of rock in the original concrete; the bands, to the cement mortar occupying the intervening spaces. It is perhaps true that the comparison may be extended farther. There is some reason to think that the pure iron operates as a binding material holding the grains—or crystals—together.

The grains themselves have been found to consist of layers or films of pure iron and layers of films of a hard substance called CEMENTITE. The layers of these two substances alternate with each other; there will be a layer of iron, then a layer of cementite —and so on. These layers are incredibly thin. Indeed, they are so fine that they remained undiscovered until a few years ago.

Consider now what our piece of steel is like. We have a very complicated network of pure iron. The word "network" is not a very good one, as it suggests strings or threads. What we have are films or layers. Let us use "network" then with this difference in mind. We have, first of all, the main network consisting of the layers which separate grain from grain. Through each grain, however, numerous layers of pure iron run, connecting the iron of the main network. In the case of our 0.50 per cent carbon steel, the layers of iron in the main network are much thicker than those which run through the grain. Between the thin layers of iron lie the thin layers of cementite.

Now the grains of the very same piece of steel may differ in size in accordance with the treatment the metal has undergone. For example, if the steel has been heated to within 400 or 500 degree F. of the melting point, and then allowed to cool, the grains will be much larger than if we heat only to 1500 degrees. In fact there is an infinite number of grain sizes. These vary in accordance with the temperature at which the heating is stopped. That is to say, for our particular piece of steel there will be a range of grain sizes corresponding to the temperatures from about 1425 degrees up to near the melting point—the higher the temperature the larger the corresponding grain size.

The reader will see the importance of the grain size upon learning that the strength of the steel decreases with the increase of the size of grain. This is an important fact and should be thoroughly grasped. Just why the strength should be less when grain is larger is not fully known. The writer would suggest the following as perhaps a partial explanation. The total amount of pure iron in the main network probably remains about the same for any given piece of steel whatever the temperature from which cooling begins. The total volume of material in the grains would consequently also remain about the same. The distribution would vary for both. The larger the grains the smaller their total surface would be. This would make the thickness of the layers of iron in the main network greater. Let us ask ourself the question which will be stronger, a given weight of pure iron divided into thick layers, or the weight divided into thin layers? We would expect, would we not, that the thinner the layers the greater the strength? If this supposition be correct, then we would seem to have some explanation of the increased strength of the piece of steel when the grain is smaller. However, whether this be the reason or not, the fact itself remains—the steel is stronger when the grains are smallest. This seems to be a general truth, good for pretty much all varieties of steel.

Now in the process of welding we have heated the steel on the faces of the V-shaped

groove to or near the melting point, and the whole of the added steel has been melted. All this material we have heated to a very high temperature. The grain size will be at a maximum, and the strength at a minimum. The steel in adjoining parts of the work will have to be heated to a high temperature, though not to the melting point. Indeed, we may have pretty much all possible temperatures from the melting point down if we consider the metal of the work from the faces of the groove back. We may expect, therefore, all sizes of grain from the largest to the smallest. We will accordingly have all the corresponding variations in strength. The welder must face this matter. The problem is not, however, a peculiarity of acetylene welding. There is no system of welding that is exempt. The blacksmith will not heat to the melting point and will thus not produce the very largest grains. But he will get large grains and weaker material. His use of the hammer in effecting actual union will no doubt be productive of some benefit. Any method in accordance with which a high temperature is reached may be expected to produce a large grain and decreased strength from the very fact of heating. The question of restoration will have to be dealt with if the best results are produced.

Now it is ordinarily possible to restore good steel to its original or best size of grain. This also is an important fact. If the metal has not been "burnt," it will usually respond to proper treatment. There are two general methods of restoration. First, there is the reheating process; and second, the mechanical or forging method.

In order to supply the reheating procedure, it is necessary to make sure that the steel has first been cooled below a certain pretty definite temperature. This temperature is about 1275 degree Fahrenheit. It is necessary that not merely the surface of the metal be cooled to this point but the interior as well. In fact, if we neglect any part, whether inside or outside, we can not expect restoration for that part. Now, ordinarily the cooling procedure is very easy to carry out, for the reason that we do not have to check it at 1275 degrees, but may let it go as far as we please. So that by carrying it far enough, we are able to make sure that whole is cool enough. We can cool to the ordinary atmospheric temperature if we like. The same temperature of 1275 degrees applies to all carbon steels, whatever the carbon percentage.

In carrying out the reheating, one does not have quite so easy a rule. We are, in all cases, however, to reheat the steel to a point above 1275 degrees. How far above depends largely upon the carbon content.

Steel is a very complex material. It is impossible to make commercially a perfectly uniform metal. The carbon percentage may vary slightly. Even if we could be certain of the carbon, other substances such as manganese, sulphur, phosphorus, silicon will occur in varying percentages. Absolute uniformity of steel from one melting to another is practically unkown. Indeed uniformity of the product from a single pouring is not to be expected. One part of a steel ingot will differ slightly from another part. We have in these facts a partial reason, perhaps, why in reheating it seems advisable to reach a temperature somewhat in excess of the theoretic one.

It needs to be emphasized that carbon is not the only substance in steel which controls the temperature of restoration. The statements and principles of the preceding pages are therefore to be regarded as general guides to the workman. They will probably cover usual requirements. There are other cases where the importance of the particular work in hand or the fact that a great deal of work is to be carried out with the very same steel will justify further efforts. Metallurgy does not seem as yet to have obtained a formula such that with its aid we may determine the best restoration temperature with exactness and certainty as soon as we know the chemical composition of the steel.

It would seem to be thought by some that slow cooling is essential. Slow cooling is advantageous, no doubt, in avoiding cracks from contraction: it gives opportunity for adjustment and the like. There would, however, seem to be no special advantage from the point of view of restoration alone. That is to say, if every part of the metal to be restored has been cooled thoroughly and then reheated in such way that every part—inside and outside—has reached the temperature of best condition without exceeding it more than a few degrees, then a slow cooling would appear superfluous. The foregoing account has shown how these results may be attained.

There is a quicker though less perfect method, however. The steel to be restored may be reheated, subsequently to a thorough cooling, until externally it is well above the point of restoration. If the cooling from this point is now retarded, the interior will have opportunity to absorb heat from the exterior. In this way the interior may perhaps attain the restoration temperature. And this is a good result. On the other hand, it has been attained at the expense of overheating the exterior and producing there a condition different from the best possible. The acetylene welder is advised to use this method only when a better procedure is, for some reason, impossible. It would probably in most cases be about as easy to hold the temperature of the exterior at the restoration point (annealing point) until the interior has come up to thermal equality.

Mechanical Treatment

It has been found that the grain size may advantageously be broken up by mechanical means. Thus forged steel and rolled steel are much stronger than cast steel. This fact is to be attributed principally to the reduction in grain size. Railroad rails are formed by rolling and are in consequence very much stronger than they would be if cast.

The methods of securing the very best results do not seem to have been as yet thoroughly worked out by steel metallurgists. At the same time it will be well for the acetylene welder to understand the main features of what appears to be the best procedure. In the case of mild steels, mechanical treatment can be commenced at a high temperature. But, if begun, it should be continued without intermission down to the point of final stoppage. The welder will use a hammer or some other tool. Mechanical treatment should be stopped when the steel has reached the temperature corresponding to the finest or best grain size. Preceding paragraphs treat of this temperature. In any case, he has continued the treatment far enough when the steel is attracted by a magnet. In some cases he will perhaps have gone too far. The suggestion is made by the writer that the acetylene welder may find it useful to use a hammer head that has been magnetized. A piece of hardened tool steel can be permanently magnetized. When the hammer begins to stick it is time to stop.

The statement cannot be made in any final way, but it would seem doubtful whether hammering during the progress of the welding operation is beneficial. Hammering or forging of the finished portions is recommended, if the foregoing directions are carefully followed. The annealing, or restoration, of the material which has been involved in high temperature should, if possible, be carried out in all cases, whether forging has been done or not. The restorative effects of a thoroughgoing annealing process are very penetrative; forging is frequently not so.

"Steelkote"

Trade name for flux coated steel electrodes for general steel arc welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chi-

cago, Ill. See Table of Contents, Catalog Section.

"Steelweld"

Trade name for welding wire for steel castings. Made by Steel Sales Corporation, Jefferson and Adams Sts., Chicago, Ill. See Table of Contents, Catalog Section.

Stellite

Stellite is an alloy of semi-rare metals containing no iron. It is very hard and resistant to the corrosive action of alkaline solutions. Stellite is used principally for machine tools, on account of its great hardness. The metal is so expensive that in making tools with it just enough Stellite to hold the required edge is welded to a steel shank. Gas welding and resistance welding have been used to weld Stellite tips but one manufacturer says that arc welding gives a better looking job. One of the electrodes is attached to the steel shank and the other electrode is a short length of soft iron wire. The V between the tip and the shank is filled in by melting the electrode.

Stirrup

The yoke connecting the diaphragm of a pressure regulator and the valve disc.

Straightedge

A steel rule, or the planed edge of a bar, which is used for lining up parts to be welded. Channel irons are sometimes used for this purpose.

Strainer

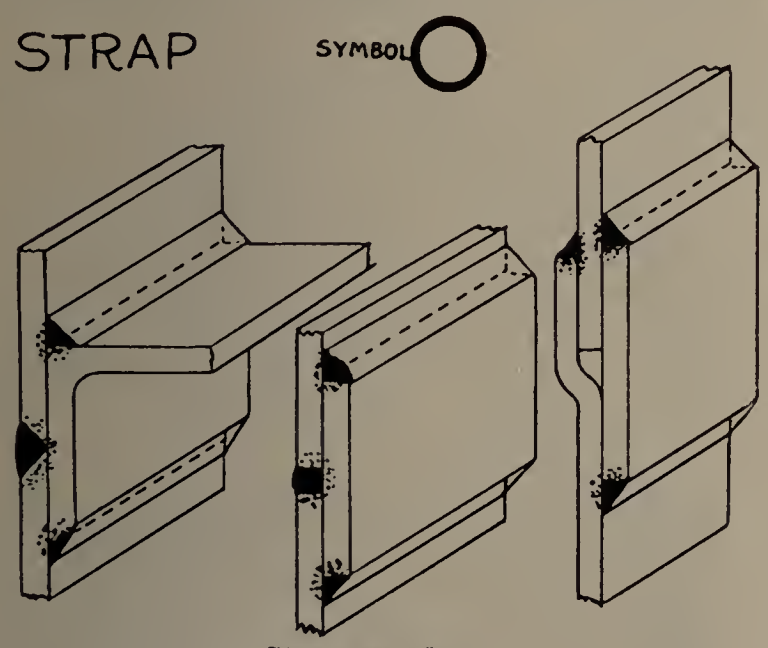
A part of an acetylene generator which collects the dirt and substances in the gas, Usually made of fine mesh wire cloth.

"Strand"

Trade name for flexible shaft grinders. Made by N. A. Strand & Co., 5001 N. Lincoln St., Chicago, Ill.

Strap Weld

A STRAP weld is one in which the seam of two adjoining plates or surfaces is reinforced by any form or shape to add strength and stability to the joint or plate. In this



Strap Weld.

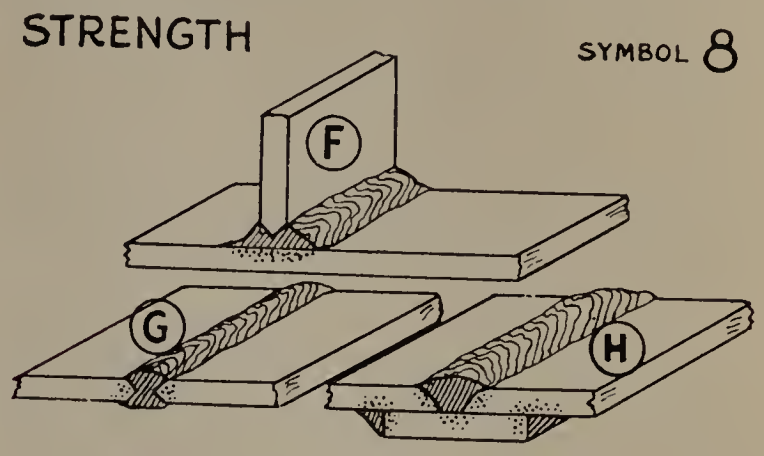
form of weld the seam can only be welded from the side of the work opposite the reinforcement, and the reinforcement of whatever shape must be welded from the side of the work to which the reinforcement is applied.

Street Gas

Illuminating or city gas used in connection with oxygen for cutting. The illuminating gas must first be stored under pressure. This mixture, while said to be satisfactory for cutting, is not a success for welding, because of the presence of water vapor. See "Oxy-Coal Gas."

Strength Weld

A STRENGTH weld is one in which the sectional area of the welding material must be so considered that its tensile strength and elongation per square inch must be equal at least to 80% of the ultimate strength per square inch of the surrounding material. (To be determined and specified by the designer). The welding material can be applied in any number of layers beyond a minimum specified by the designer.



Strength Weld.

The density of the crystaline metals is NOT of vital importance. In this form of weld the "design of weld" must be specified by the designer and followed by the operator.

Stromberg-Slaughter

The metallic electrode arc welding process using a coated electrode. Can be used with either A. C. or D. C. current. See chapter on "Electric Arc Welding."

Structural Steel Welding

The sketches in Fig. 1 show some special applications of joining two or three or even more of the regular structural members for structural work. When joining two plates at an angle, if the sheets are left a bit spread the pieces can be joined reliably in the one weld. The wider the plates are apart, the more reliable will be the joining of the inner three pieces and at no time should the plates be apart a smaller distance than their thickness. The illustration to the right of this shows a method of stiffening a sheet either for attaching to an upright or not. The angle bending and welding method shown in the center top is one of the most widely used applications of arc welding, but

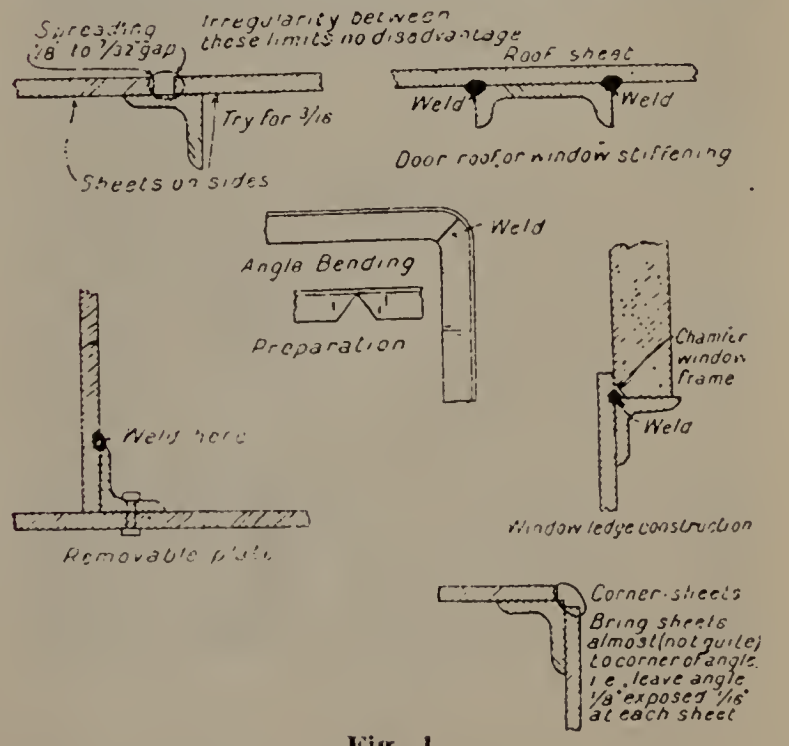


Fig. 1.

is shown as an idea to extend the arc as arc welding is only started. You will note that any angle can be allowed for by cutting out the "V" to correspond. The illustration to the left of this shows a method of joining by a combination of arc welding and bolts, members which must be removable. The window frame method itself is self-explanatory, it being found much easier to

chamfer off the edge of the window slightly than to cut out the corner of the angle and try to make a flush weld and perhaps ending by having to chip the weld afterward. The corner sheet method is very similar to the joining of the three pieces explained at the start of this section. Where an angle would be objectionable or the plates are small the weld can be made from the inside forming an angle of the weld with the two plates. The plates can then be butted on the outside at a right angle and not welded at all or just welded for finish only.

An example which marks the beginning of the application of arc welding to building construction is to be found in the case of a building erected by the Electric Welding Company of America at Brooklyn, N. Y., for its own use.

Before proceeding with the work of erecting the building entirely by arc welding, it was necessary to obtain permission from the various city building departments, and such permission could only be given if certain tests were made which would satisfy the building officials that a welded structure would be absolutely safe and would compare favorably in other respects with a riveted steel framework.

Certain samples of welded joints were requested for the tests. The samples submitted and the test results were as follows:

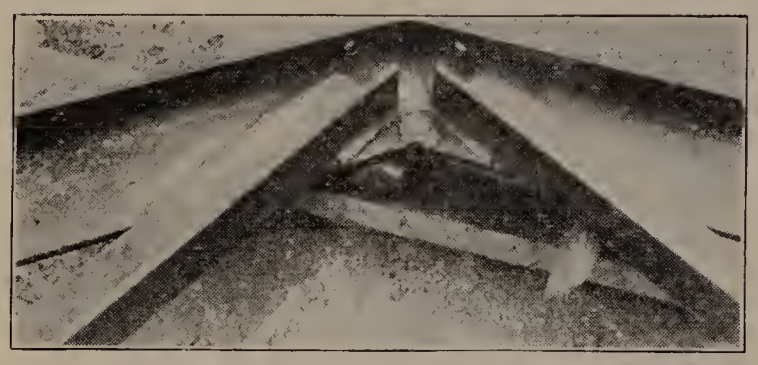


Fig. 2.

First sample, 1¼ in. by ⅜ in. lap welded bars, lapped 1¾ in. and welded across the edges; when subjected to a direct tension of 60,000 lb. per sq. in. a break occurred in the bar 3 in. from the weld. Examination at the line of union between the added and parent metal showed no distinct boundary between them.

Second sample. This sample consisted of two angles (2 in. by 3 in. by ⅜ in.) set at right angles and welded at the intersection. This sample was set in a machine so that there was a horizontal lever arm of 8 in. from the center of pressure to the center of weld and intersection, and developed a beam load of 11,375 lb. at the weld, or a torsional stress of 91,000 lb. at the weld, with no apparent distress to the weld.

The tests of these samples were entirely satisfactory to the building officials. Permission was subsequently given to proceed with the erection of the steel framework, but there was still another test to be made of the steel trusses of 40 ft. span, which were to be used to sustain the roof. These trusses were of fan type of design and all members were electrically welded together, no bolts or rivets being used. The trusses were spaced 20 ft. apart, supported by 8 in. by 8 in. H-beam columns 19 ft. high; on the sides of these columns brackets were fastened to carry an overhead traveling crane of five-ton capacity. The weight of each truss was about 1,400 lb.; the top and bottom chords were composed of 4 in. by 5 in. by ⅜ in. tee irons; the struts were 3 in. by 2 in. by ⅜-in. angles; the purlins were 10-in., 15-lb. channels.

The trusses were designed for a live load of 40-lb. per sq. ft., each truss supporting a panel of 800 sq. ft. They were tested at a load of 120 lb. to the square foot, or a total load of 48 tons on the two trusses. The load consisted of gravel in bags which were piled

Fig. 3.

in teers on planking arranged for the purpost.

Readings were taken at different increments of the loadings for the deflection in the truss or members. One of these welded members is shown in Fig. 2.

The trusses were left under load 48 hours and a reading taken showed—East support settled $\frac{15}{16}$ in., West support ¾ in. actual; point No. 2, $\frac{7}{16}$ in. actual; point No. 4, ½ in. actual deflection; point No. 3, $\frac{9}{16}$ in. actual deflection. Two days afterward the load was entirely removed and readings taken at this time showed all points in the trusses had returned to their original positions, leaving no permanent deflection except at point No. 3, where there was a deflection of $\frac{1}{16}$ in.

A more recent and wholly successful application of arc welding to the construction of structural steel buildings has recently been described by Mr. D. C. Tracy in **The Welding Engineer.** The building in question is located in the Schenectady Plant of the General Electric Company. Its dimensions are 40x40x40 inches, and 34,339 pounds of structural steel being used in its construction.

Among the savings mentioned, by far the most important are those of time, labor and material. While it would be difficult to make the first two, as effected in this case, the arbitrary basis of a statement as to just what savings can be expected on all similar jobs, owing to the purely local conditions under which the work was done, they are sufficient to prove that the economy in any case would be great enough to warrant serious consideration. As to the third factor, material, the economy will be in direct proportion to the size of the building to be erected. With regard to time alone, it has been estimated that, in the case of this particular building, if riveted construction has been used, it would have been necessary to mark and punch 4500 rivet holes in the shop, and to drive some 1800 rivets in the field. As a matter of fact, the time involved in punching was absolutely eliminated, and that in marking greatly reduced. The pieces were simply cut to length, and fabricated as far as possible in the shop, as shown in Fig. 3.

The saving in labor was correspondingly great. The ordinary gang for riveting consists of at least four men, the heater and thrower, the catcher and sticker, the bucker or holder on, and the driver. The welding gang on the other hand may consist of one man, although it is desirable to employ a welder and one helper in fabricating the parts before tacking. The difference in labor charges between these gangs is too obvious to require comment. Without regard to the time that it might have taken to put up the

building with rivets it actually took 186 welding hours, including the fabrication in the shop, to erect it with the electric arc.

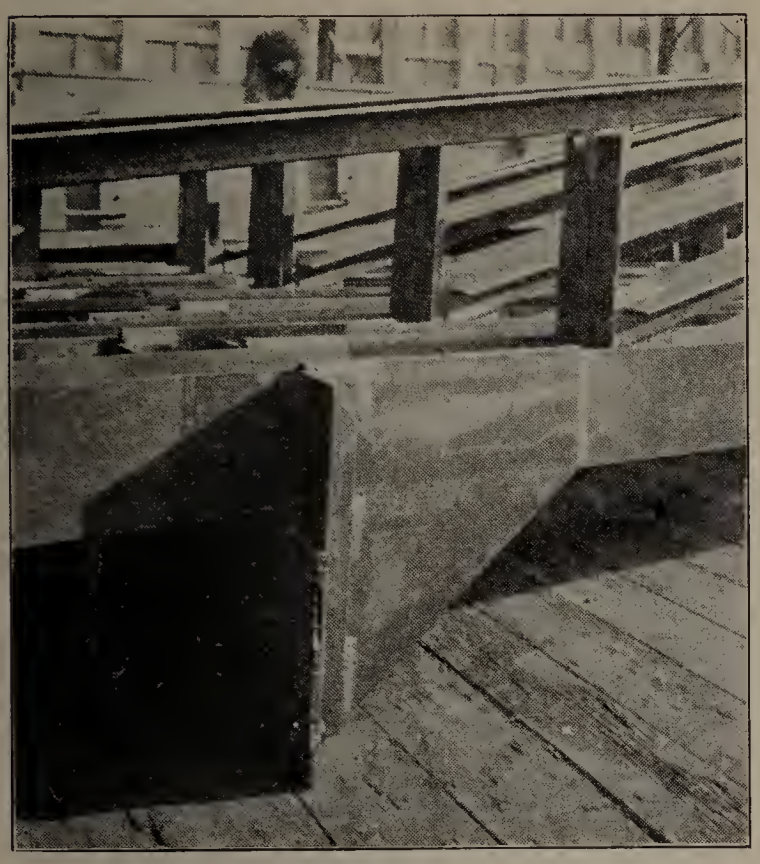


Fig. 4.

In material a saving was made which is represented in weight and cost by the difference between those of 1800 ¾-inch rivets, with a weight of over 1,000 pounds, that would have been necessary, and those of 150 pounds of mild steel welding wire, that was actually used.

Figs. 4 and 5 give a good idea of both the details of construction and the general appearance of the framework as completed. The bracket shown in Fig. 4 is one of eight which are used to support the runway for

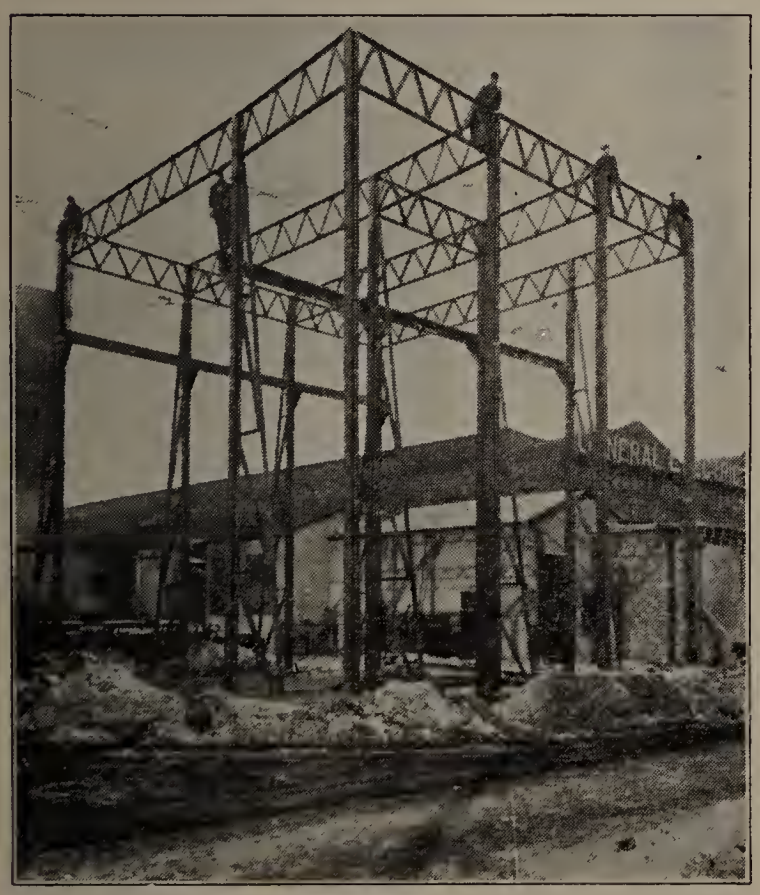


Fig. 5.

a five-ton crane. This runway is visible just over the roof of the building in the background of Fig. 5. The bracket consists of two gusset extensions welded to the main support, and a cross plate welded to angle irons, which are in turn welded to the flat surfaces of the gussets. The illustration also shows the method of fastening the bracing structure to the main column.

The construction of this building was only attempted after numerous tests had been made, and the practicability of the process determined by the observation of the results obtained in the construction of similar projects on a smaller scale. The first of the latter was the construction of a bridge joining two sections of one of the buildings of the plant, and is shown in Fig. 6. This illustration is an interior view, and gives a clear conception of the method used in connecting the gusset plates, angles, roof trusses, and framing angles. It can be plainly seen that short fillet welds were used throughout the complete assembly instead of a continuous weld. Previous tests had determined that a continuous fillet weld was not necessary for the strength required in this construction.

The second undertaking consisted in the erection of a crane runway in one of the factory buildings. The majority of the parts were fabricated in another shop, and brought to the place of installation, where they were assembled. This was accomplished so as to occasion no interference with the production work carried on in that building. The crane has been in daily operation on the runway for the last six months without trouble of any kind being experienced.

In the meantime a number of tests had been carried on to ascertain the value of the stresses that could be safely applied to welded joints. The engineers in charge were sufficiently satisfied with the result of these tests, and with the success of the structures mentioned above, to try out the process on the larger scale represented by the welded building. Its progress has been such as to justify the prediction that the future holds great possibilities for the erection of structural steel parts by the process of electric arc welding.

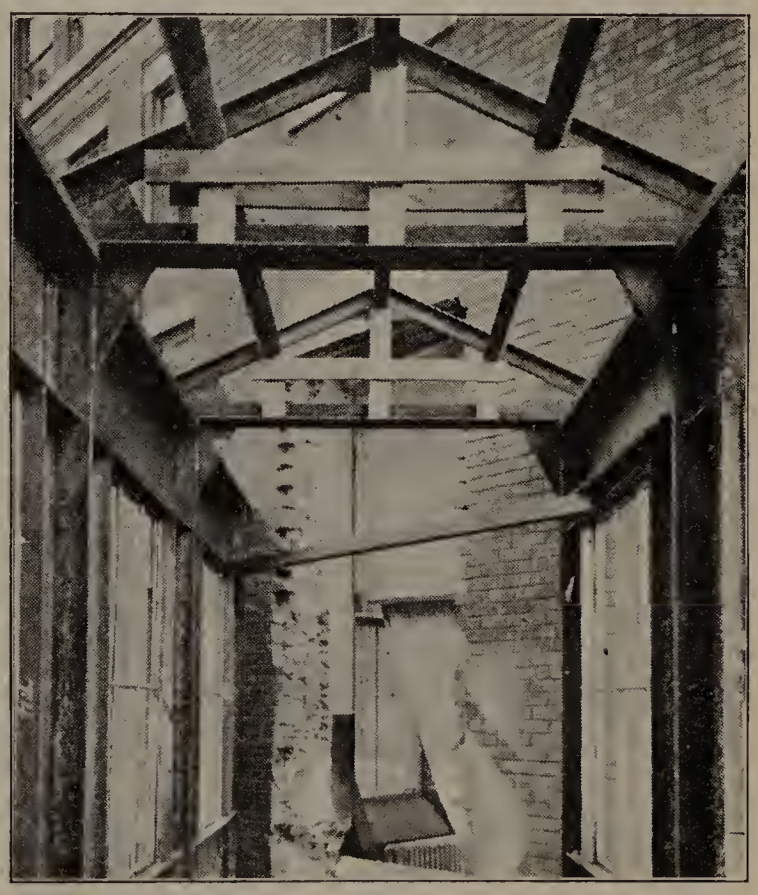


Fig. 6.

In conclusion it should be appreciated that in order to get the best results in this class of work, not only should the services of competent welders be secured, but the metal itself should be rendered free from rust, oil, or surface scale. Any one of these, if present, will tend to make the arc unstable, as well as introducing into the deposited metal a portion of oxide, which will create a weakened section through the welded portion. Too much care cannot be

exercised in the preparation of the parts to be welded, since this can be very easily done with a roughing tool, a small portable sand blast, or a stiff wire brush.

One of the most important fields of application of the electric arc welding of structural steel numbers, angle irons, etc., is found in the ship building industry. A group of the designs of joints which have been successfully used in this work will be found in the section devoted to charts and tables.

Studding

Distributing steel studs along the face of cast iron parts to be welded with the metallic arc process so that the weld cannot pull away from the cast iron. A steel electrode is used. See chapter on "Electric Arc Welding."

Stuffing Box

A device for preventing gas from leaking in the vicinity of the needle valve stems and high pressure valve stem of the cutting torch, etc.

Sulphur

A metallic element. It is as undesirable as phosphorus because it causes brittleness.

Sulphuric Acid (H_2SO_4)

Vitriol, or oil of vitriol.

"Sun-Lite"

Trade name for compressed acetylene. Made by Gas Tank Recharging Co., Milwaukee, Wis.

Superheater Units

These units are often cracked on the return end. One method of welding, which has been recommended is to cut off the end, about one inch in order to get into good material. A cap of ¼-inch material is then welded on. By using a cap the weld will be on the side of the unit instead of on the end and the greatest heat will strike the cap, which is the thinnest part, and will stand this heat as the steam passing through will keep it cooler.

"Superior"

Trade name for welding and cutting torches, accessories, supplies, acetylene generators, etc. Made by Superior Oxy-Acetylene Machine Co., Hamilton, Ohio. See Table of Contents, Catalog Section.

"Superior"

Trade name for a brazing compound. Made by Standard Mfg. Co., 947 W. 20th St., Chicago, Ill.

"Superior"

Trade name for oxyacetylene torches. Made by Air Reduction Sales Company, 342 Madison Ave., New York City. See Table of Contents, Catalog Section.

Surface Hardening

This process should not be confused with case-hardening. In case-hardening the excess carbon purposely produced in the flame changes the chemical composition of the steel being treated, while keeping it hot. In surface hardening heat is applied to the surface of a piece of steel while the rest is kept cool with running water or other devices. The oxy-acetylene torch furnishes a cheap and rapid method of hardening; it is applicable to such purposes as the hardening of the surface of gear teeth, castellated shafts and bores, template holes, and in general to the localized hardening of any small area on large articles, particularly where the ordinary hardening process would cause distortion that would be difficult to remove afterwards by grinding.

The work to be hardened locally is placed in a tank of water with an adjustable overflow, so that the water level can be regulated, as while the surface to be hardened is instantly heated to the required temperature the remainder of the article is kept cool by water flowing over the surface. The tip is held so that the outer portions of the flame flow in the direction along which the tip is traveling and the portion of the steel heated should be cooled, when intense hardness is desired, by arranging that cooling water shall flow as close as possible to the traveling tip, but not so close as to disturb the flame, because that not only is liable to put it out but prevents rapid heating and causes irregular hardening.

The flame should be of very high temperature, so that it will burn close to or even under water. A high temperature can be obtained by adjusting the flame as for welding and then increasing the pressure of oxygen so the flame changes appearance from a white cone to a bluish streaked tongue, when observed through welding goggles. It should be remembered that success depends upon rapid heating.

A very thin and very hard surface will be obtained if the part to be hardened is held just below the surface of the water so that the flame has to blow away a film of water. A deeper hardening, on the contrary, is obtained by prolonging the heating, and while doing this the operator should give a slight rotary motion to the torch to avoid burning the metal.

"Svea"

Trade name for Swedish iron welding wire for oxy-acetylene and electric welding. Made by Federal Tool and Alloy Steel Corporation, 62-76 Rutledge St., Brooklyn, N. Y.

Sweating

See "Silver Soldering"

"Swedox"

Trade name for welding rods and wires, and coated electrodes. Made by Central Steel and Wire Co., 127 N. Peoria St., Chicago. See Table of Contents, Catalog Section.

Swish Weld

Used on medium work and for finishing on heavy metal. Makes a smooth, easily finished weld. The Swish weld is completed by holding the tip almost vertical to the plane of the weld, with handle at right angle to same, although on heavier work it is often more advantageous to work in line with the weld. When edges of the metal arrive at the melting point, wire is held before the small cone, as the fusion point is attained the torch is brought forward by a sharp movement of the hand. This action places the drop and swishes the molten metal ahead, leaving a comparatively smooth path. Also used in finishing boiler welds, and many others that do not require grinding or filing.

Switch Points

See "Frog Points."

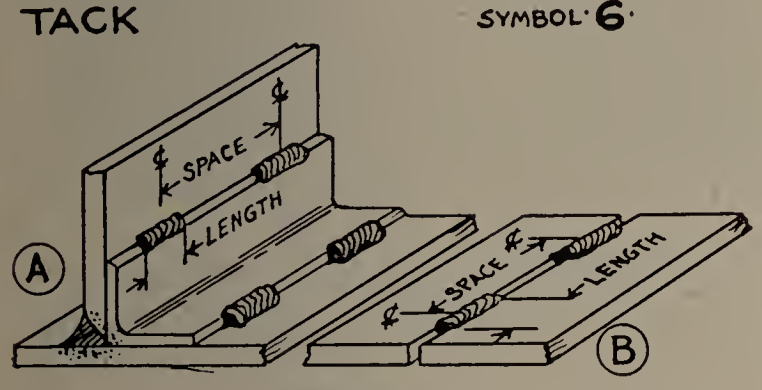
—T—

"T"
Trade name for bronze, manganese, copper and aluminum welding rods. Made by Chicago Hardware Foundry Co., Chicago, Ill.

T Spot Weld
See under "Spot Welding" in chapter on "Electric Resistance Welding."

Tacking
Drops of molten metal applied at points on the welding line, for the purpose of holding the pieces to be welded until the actual welding operation is well under way and there is no further danger of the pieces shifting position.

Tack Weld
A tack weld is applying the welding material in small sections to hold two edges together, and should always be specified by



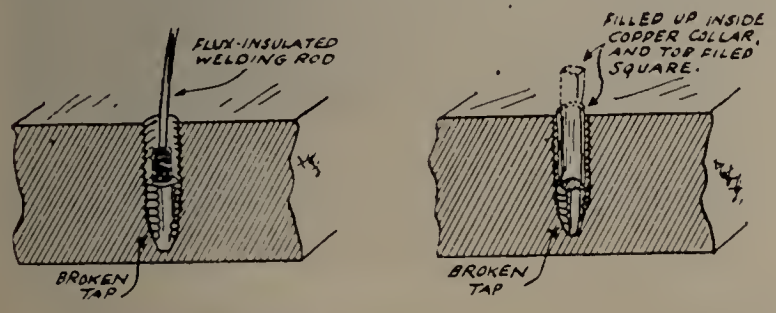
Tack Weld.

giving the SPACE from center to center of weld and the LENGTH of the weld itself. No particular "design of weld" is necessary of consideration.

A tack is also used for temporarily holding material in place that is to be solidly welded. until the proper alignment and position is obtained, and in this case, neither the LENGTH, SPACE, or DESIGN OF WELD are to be specified.

Tank
See "Cylinders."

Taps
There is nothing more exasperating than to break a tap, especially a bottoming tap below the surface of the main piece. The tap must be gotten out or the work is ruined. If the hole is large an insulated rod can be used to build up on the tap until it is above the surface where a square can be filed on it and the tap backed out. The insulation on the rod helps to prevent spoiling of the thread by accidental contact. The method here is to weld a bit at



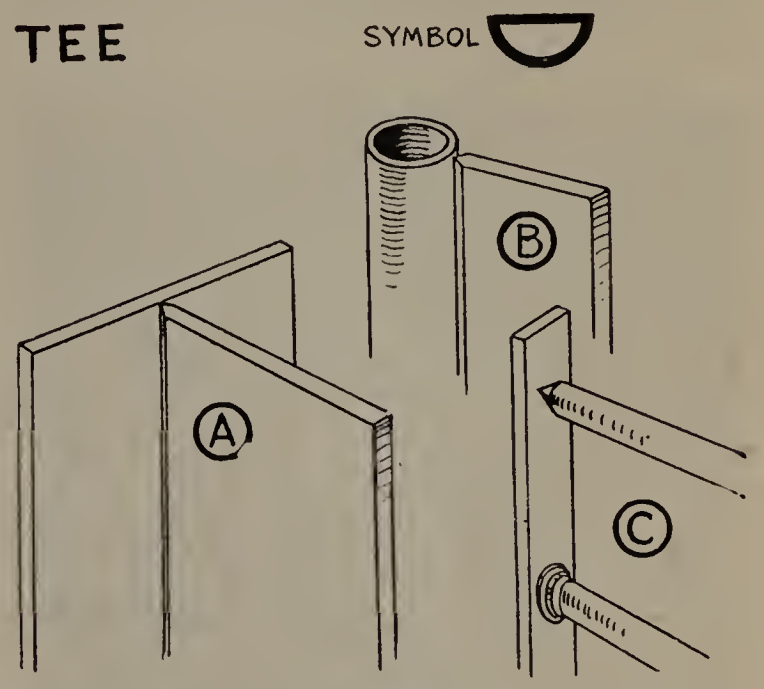
Removing Broken Taps.

a time or if you have become expert at dipping in and out of the puddle, the building-up can be made practically continuous by shorting the arc in the puddle and pulling away to a very short arc before the puddle freezes. This method is also very useful in building-up ofttimes at other places than in a hole. Where the hole is small an extra tube shoved down inside the threads will allow of the added metal being built-up to the surface in order to file a wrench grip to back out the tap.

Taylor Process
A special adaption of the electric resistance spot welding process, employing a double electrode.

"Tecor"
Trade name for electrode holders, masks hand shields, etc. Made by Transportation Engineering Corp., 200 Fifth Ave., New York, N. Y.

Tee Weld
A Tee weld is one where one plate is welded vertically to another as in the case of the



Tee Weld.

edge of a transverse bulkhead being welded against the shellplating or deck. This is a weld which in all cases requires exceptional care and can only be used where it is possible to work from both sides of the vertical plate. Also used for welding a rod in a vertical position to a flat surface, as the rung of a ladder, or a plate welded vertically to a pipe stanchion, as in the case of water closet stalls. These cases are illustrated in Figure 1.

Tempering
The oxy-acetylene flame has proven highly efficient for tempering, especially in the case of hack-saws and band-saws which must have a hard cutting edge while the body of the plate remains relatively soft. The old method of tempering these saws was to pass them through a slot in a water cooled cast iron block, above which only the teeth of the saw would project. A flame made by compressed air and city gas was directed against each side of the saw until the upper part was brought to a tempering heat when the saw was quenched in oil. Production by this process is both slow and unsatisfactory. The heat is often conducted into the body, resulting in tempering a considerable portion of that part of the saw which should be ductile. These conditions have been removed by the use of the oxy-acetylene flame. which makes it possible to confine the tempering to the teeth, and to produce a soft bodied saw. See under "Broach."

Tensile Strength
Resistance to breaking, which metals offer, when subjected to pulling stress.

"Tensil"
Trade name for a solder used for black iron, brass, lead, nickel, tin and zinc. Made by the Rohde Laboratory, 17 Madison Ave., New York. N. Y.

Testing Welds*
The question of testing welds is one that has been considered more or less since welding was known, but especially during the past five years. Its importance has now

**Written by S. W. Miller for The American Welding Society, Chicago Section.*

become very great. There have been many failures in the past, many of them not having been explained and some of them having been very expensive. As in all other developments, welding first received its principal impetus from the practical man. Of late, however, the tendency has been to investigate more carefully and more fully and by means not available to the ordinary welder. This means that scientists of all kinds have been called into consultation and that almost every conceivable method of test has been suggested in order to determine what methods and materials would make the best welds both from a standpoint of security, service and cost. While some of the methods employed at present are beyond the reach of the ordinary welding shop yet they are of great value and, in fact, necessary in

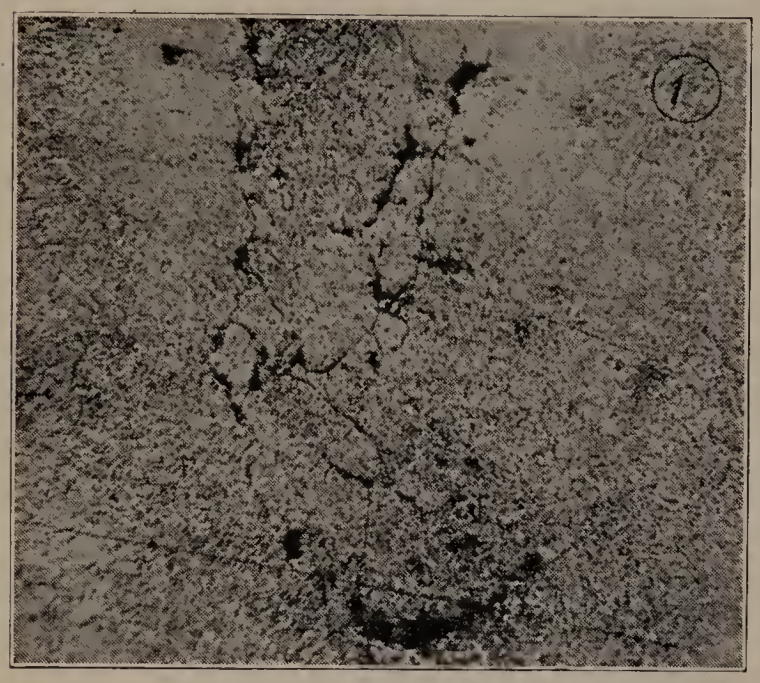


Fig. 1.—Flaky Gun Steel. Films of Oxide or Slag, Which Weaken the Metal, and Prevent it Passing Test.

order to determine correctly what has occurred during the welding operation and what results may be expected under given conditions. Serious criticism of most of the published results can be made because of

Fig. 2.—Strained Piece of Gun Steel Showing Rupture Beginning at Small Defects, Two Small Dots of Manganese Sulphide.

their incompleteness in one or more respects and one of the things that the American Welding Society proposes to do is to put the testing of welds and welded structures on a firm and safe foundation.

The testing of metals, aside from welds, is quite well developed both in theory and practice. The usual test is the tensile, which gives the tensile strength per square inch, the yield point or elastic limit in pounds per square inch, the elongation in per cent of the original gauge length and the reduction of area in per cent of the original section. Compression, torsion, shock and alternating stress tests are also used and the two latter are beginning to be used much more than they have in the past because it has been found that materials may give high results in the tensile test and yet be entirely unsuitable to resist service where shock or alternating stresses are met. Another of the common tests is bending to a certain radius either hot or cold and it has been found that it is a very valuable test of certain qualities.

Chemical analysis is another powerful method of investigation and many specifications have been made in which its use is vital.

The microscope has been found to be of tremendous help in the study of metals and in fact it is now a necessary instrument in all laboratories. Its principal function is to determine the extent and location of impurities in a metal, to decide whether the structure is proper for the purpose desired and to decide whether various heat treatments will give satisfactory results. While no one method of test shows everything desired to be known, the microscope is probably the most powerful single method of investigation in the case of metals, and in the study of welds it is particularly valuable because of the method of their formation. A weld is a casting and is subject to all the defects found in castings which are, however, exag-

Fig. 3.—Another Piece of Strained Gun Steel. Rupture Occurs Here In a Streak of Ferrite, Which Contains No Carbon, and So Is Weaker Than the Rest of the Material.

gerated in the case of welds. It would be impossible in the time allowed to consider the defects in welds in all metals made by all welding processes and I therefore feel that it will be wise to confine my talk tonight to the welding of steel plate by the O. A. and metal electrode processes. Let us also consider that the welds we are to talk about are to be those in some important structure so that soundness and high quality are necessary. By soundness, I mean freedom from mechanical imperfections such as lack of fusion, the presence of films or other inclusions, gas pockets, slag, etc. It is not forgotten that welds of inferior quality may

answer some purposes admirably and that if they do, there is no use in making better ones, but this is not the goal at which to aim for one who desires to make really good

Fig. 4.—Armco Iron Strained. The Curved Lines Are Not Cracks, But the Edges of Parts of the Grains That Have Slipped Past Each Other, So That the Surface of Each Grain Is Stepped, As Would Be the Top of a Row of Books That Had Slid Past Each Other. In Some Grains There Are Two Sets. They Are Called Slip Bands.

welds. The welding of steel is frequently considered as not being especially difficult and it is also sometimes considered that steel is steel and that no different treatment is required in the case of different qualities

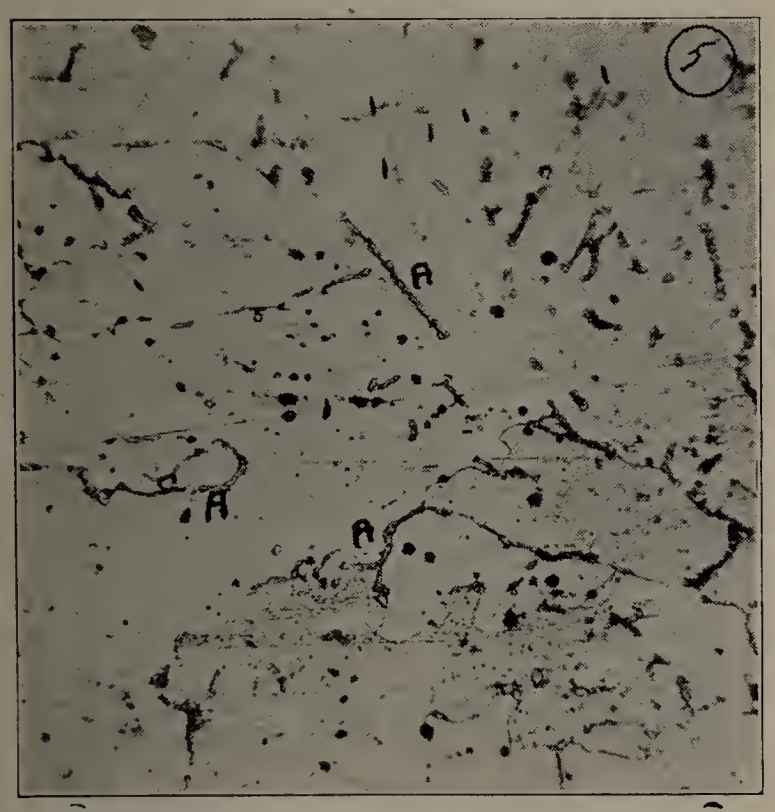


Fig. 5.—A Better Oxy-Acetylene Weld Than Fig. 6, But In the Same Material. Note the Absence of Iron Nitride Lines. The Small Dark Dots Are Iron Oxide, and They Appear In All Welds. The Bands A at the Grain Boundaries Are Carbide of Iron, or Cementite, and Contain All the Carbon in the Steel. There Are More of Them Than in Fig. 6, Showing More Carbon Present, and Also That the Metal Was Not As Hot As in Fig. 6, Because Overheating Burns Out the Carbon.

and varieties of steel. This idea is much less common today than it was several years ago, but it is still too prevalent for the good of the art. It is not as well known as it should be that a comparatively small difference in the percentage of carbon in the material being welded makes a very great difference in the results of either a bend or tensile test. If the carbon is .12 per cent or less, the material is soft, ductile and yields readily to any strain that may be put on it. Such material is frequently used for tanks and because of its ductility and comparative freedom from damage by heating, is admirably suited for welding. Structural steel, bar steel and boiler plate contain about .15 per cent to .25 per cent carbon and have a tensile strength of about 60,000 lbs., while the soft low carbon material has only about 52,000 to 55,000. Ship plate is required to have a T. S. of from 58,000 to 68,000 lbs. and in the heavier sections requires as high as .30 per cent carbon. It has been found by experience that the higher the carbon, the more difficult it is to get a satisfactory weld and the more danger there is of injuring the metal being welded. From a metallurgical point of view this is entirely natural and to be expected. It is also evident that a weld made with a given welding rod or electrode can have only a given strength. If this strength is greater than that of the material being welded, the test piece will always break outside of the weld. If on the other hand, the weld is weaker than the material being welded, the rupture will always take place in the weld. An O. A. weld made with ordinary low carbon welding wire will have a tensile strength of about 52,000 lbs. This is stronger than soft tank steel and weaker than the other materials mentioned. It is possible to get with alloy steel rods of proper composition a tensile strength in an O. A. weld of about 50,000 lbs. Neither of these materials will weld boiler steel, boiler plate or ship plate, so that the rupture will occur outside the weld when the section of the weld is the same as the section of the piece, so that in making tests of welded pieces, it is necessary to know accurately the character of the material being welded because if Welder Jones makes a weld in soft tank steel and Smith makes one in bar steel the first will break

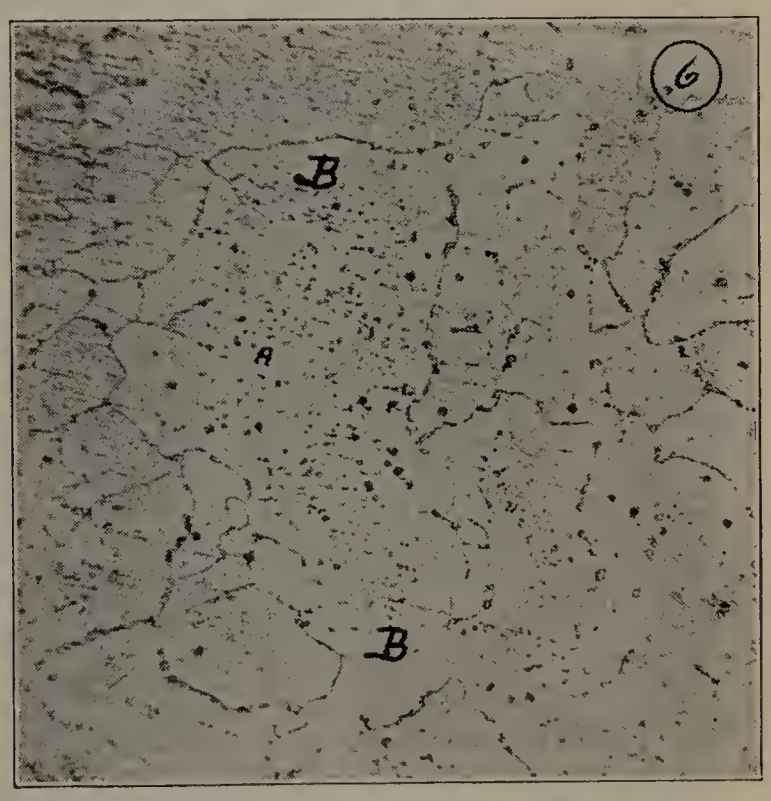


Fig. 6.—A Good Looking Oxy-Acetylene Weld, But Made with Too Large a Tip, As Shown by the Short Straight Lines in Some of the Grains, As Above and Below A, in the Large Grain B. These Lines Are Iron Nitride, and Indicate Absorption of Both Nitrogen and Oxygen By the Overheated Metal. The grain Boundaries Are the Irregular Curved Lines.

outside of the weld and the latter in the weld with a probable adverse criticism of Smith's work. The method of test to be applied in any given case depends largely

on the use to which the welded piece is to be put. If it is to be used in a pressure vessel, I believe that not only should a tensile test be made but that an alternating stress test should be used because of the breathing of the tank due to changes of pressure. This latter test should also be applied where the weld is subjected to bending strain. There are no standards at present for weld tests but it is advisable, whenever possible, to follow those of the A. S. T. M. Inasmuch as a welded piece is not

Fig. 7.—Slip Bands in Good Oxy-Acetylene Weld, Stopping At Grain Boundaries.

of uniform character, it is not possible to use the elongation and reduction of area as commonly measured. Where the break occurs in the weld, the elongation of the whole test piece tells very little about the quality of the weld and I have been in the

Fig. 8.—Oxy-Acetylene Weld Showing Heavy Slipping At Grain Boundary. This is Not a Crack, But Shows a Weakness There.

habit of taking the elongation in each inch, two inches, etc., of the gauge length beginning at the center inch which includes the weld, and plotting these figures against the gauge length. Evidently, when the break is outside the weld, the various physical characteristics are those of the original material and not at all of the weld. The best test, in my opinion, to determine quickly the general character of a weld, is to grind it off level with the surface of the pieces and clamp it on an anvil, with the center of the weld level with the top of the anvil, the bottom of the V toward the anvil so that the top of the weld is stretched when the projecting end is struck with a sledge. The blow should not be too heavy and the number of blows and angle to which the piece bends before cracking are quite a good index of the value of the weld. It is true in this test, as in the tensile tests, that the quality of the material being welded has a great influence on the results. Stiff material throwing more of the strain into the weld while soft ductile material will itself take considerable of the bend. In the case of defective welds, that is, those not fused along the V or which contain slag or other inclusions, this test will at once develop the defects If a welded piece were to be used in a place where it might become red hot such as, for instance, in a locomotive fire box crown sheet, it would be entirely proper to test the weld at a good red heat and I believe that it would be of much interest to all of you, if you would test some of your welds by clamping them in a heavy vise or on an anvil with the center of the weld about half an inch from the edge of the table or above the face of the anvil, heating them to a bright orange with the torch and then bending them as before as with a sledge.

If such welds are made in half inch by two inch bar steel, a 90 degree single V being used, and they bend to a right angle cold without cracking on the outside, a welder may feel well satisfied with his work.

It is not my intention to tell you how to make good welds, but it may be well to state that there seems to be quite a definite relation between the thickness of metal, the size of tip and the size of the welding wire, in the case of gas welding, and between the

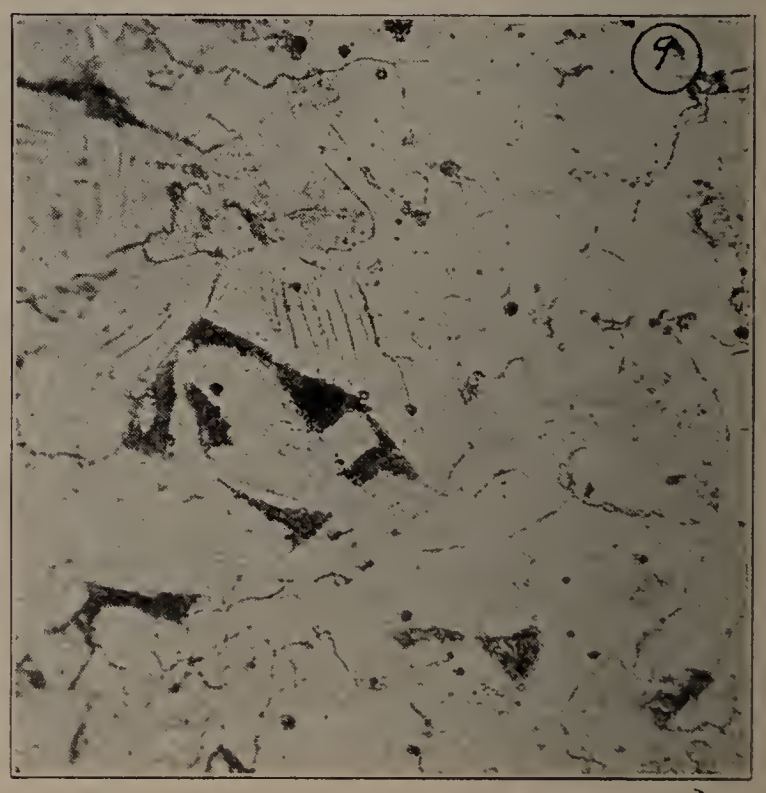


Fig. 9.—Good Oxy-Acetylene Weld Made with Rather High Carbon Steel. As Shown by the Pearlite Grains A. Note Presence of Slip Bands in All Good Welds, and Their Absence in Bad Ones.

thickness of metal, the diameter of the electrode, and the current used, in electric welding. It is also to be understood that electric welds, except possibly those made with covered electrodes, will not stand as much bending as O. A. welds.

In many cases, the defects in welds are easily visible to the naked eye when tested.

In other cases, they are not, and while it would seem plausible that the visible ones were more dangerous, yet to my mind, the hidden danger due to the ones that are hard to see is a matter that must not be overlooked. For many years, the dangerous defects in steel rails have been those which were not visible, and which have usually been very small at the start. During the war, when the demand for gun steel was

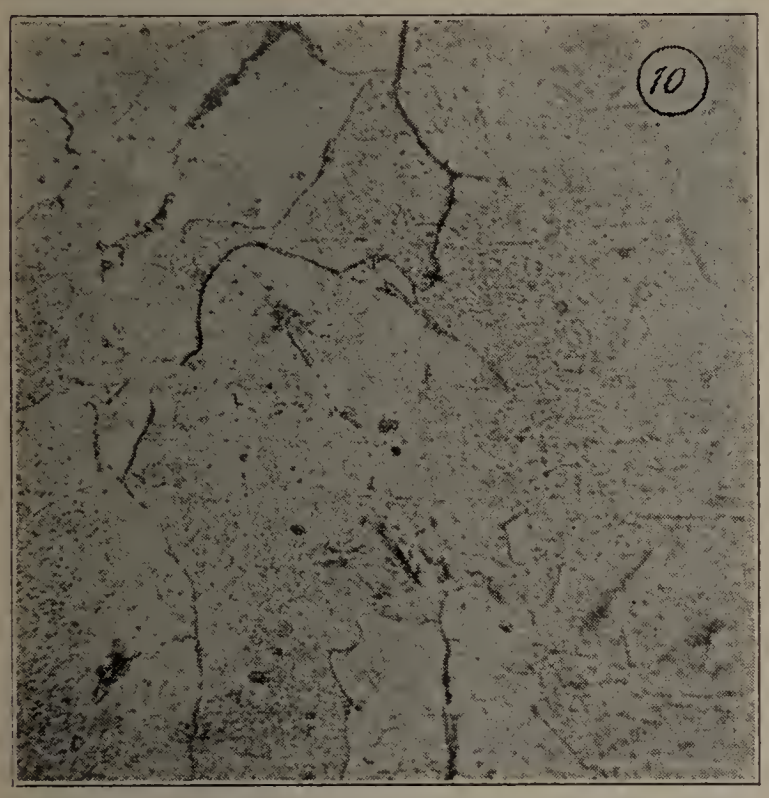


Fig. 10.—Inter-granular Cracks in Strained Oxy-Acetylene Weld.

very heavy, flaky steel, so called, was the material that gave the Government the greatest cause for concern. In fact, those who are best posted on the metallurgy of steel are paying more and more attention to the minor defects, which heretofore have been considered but of little importance. This is equally true in a case of welds and in finding out what a welder can do, this is one of the things that should be examined

Fig. 11.—Film of Foreign Matter, Probably Oxide, in Oxy-Acetylene Weld.

most carefully. There has recently been developed a method for testing rails for these hidden defects which has been devised by Mr. A. M. Waring. It consists of deeply etching a polished surface of the material under test. For instance, a section of a weld might be cut out with a hack saw, machined or filed to a true surface, and polished on various grades of emery paper, ending up with 00 Manning. It is then placed in a warm solution of 25 per cent hydrochloric acid and water for from a half an hour to an hour. The acid will eat away the defects, making the edges of the material at them taper, so that rather large grooves and pits will be visible where the defects prior to the etching would be only microscopic. It is not really necessary to warm the acid although it takes longer when it is cold. The bending test hot and cold, and the etching test, I consider to be of the greatest value in ordinary shop practice where it is desired to find out rapidly and quite accurately what the quality of the work done by the different welders is.

Some of the defects in welds are visible under the microscope but others are not visible until the weld is strained. A small bending machine that can be placed on the microscope stage is very useful, because after etching the piece can be bent and examined and see what the effect of the strain is. In the case of bare wire electric welds, the rupture, as far as my experience goes, always occurs at the grain boundaries even where no defects are visible there at the highest powers of the microscope. Of course, where there are visible defects, the rupture takes place first at these. Where there are not defects, the distortion occurs by slipping in the grains as in normal steel. The causes of these defects are to my mind almost always oxides of one or another constituent of the metal, but usually of iron. There is no positive proof of this as yet but there are indirect proofs. An electric weld that will bend very little may be made much more ductile by heating in a reducing atmosphere at a low red heat for one or two hours indicating that the weakness at the grain boundaries has been removed. The reducing atmosphere would seem to make it clear that the material at the grain boundaries was an oxide. Again, heating an electric weld in an oxidizing atmosphere makes it more brittle. The same treatment affects O. A. welds in the same way but in as much as they are normally not as brittle as electric

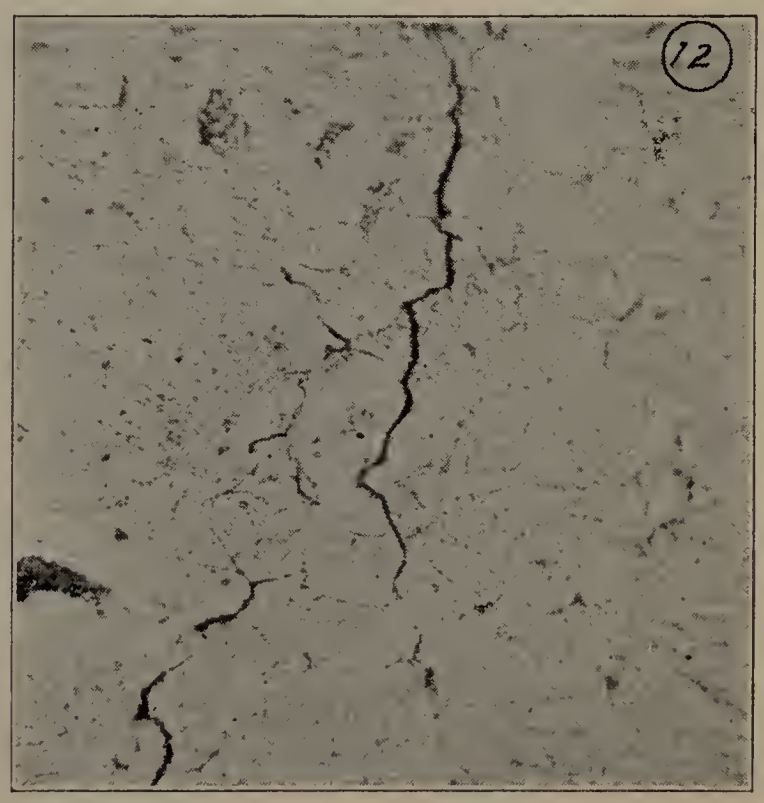
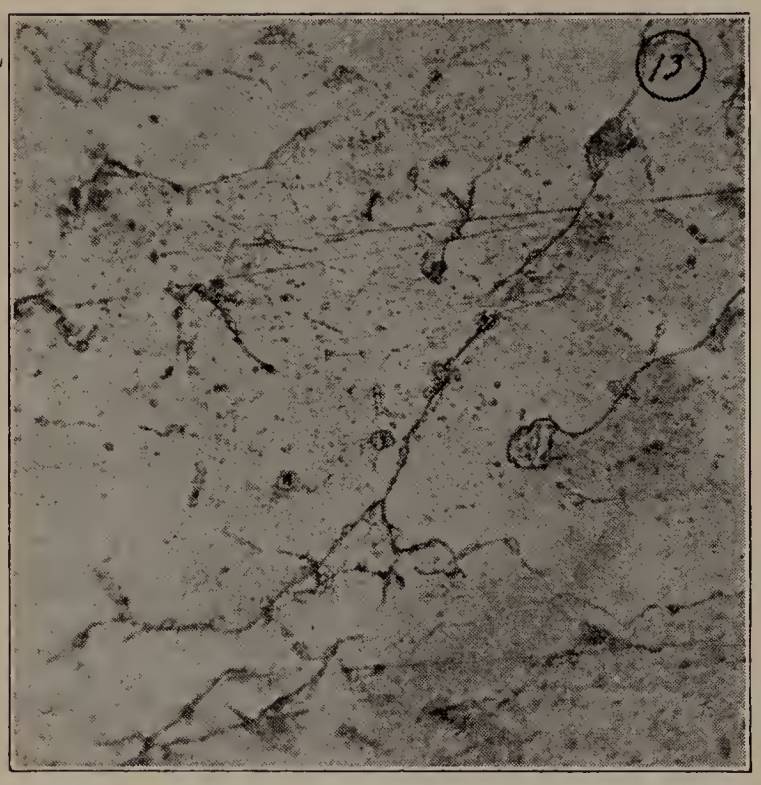


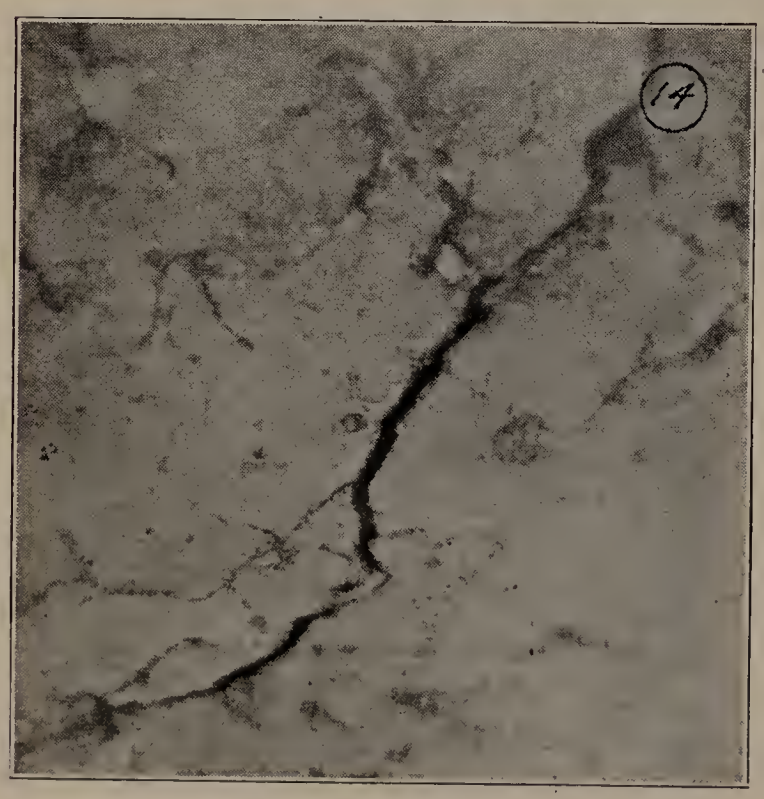
Fig. 12.—Inter-granular Cracks in Strained Oxy-Acetylene Weld. No Defects Visible Before Straining, Showing That Films Were Very Thin.

welds, the improvement is not so noticeable.

These rough tests, while satisfactory for determining the general quality of the work, do not answer as a basis for design and more refined tests must be used as before referred to. I believe that the most im-

portant of these are the tensile and alternating stress tests. The tensile test can be made in any shop provided with the usual tensile testing machine. The alternating stress test is not as yet standardized even for unwelded material. I am inclined to believe that the machine devised by the Quasi-Arc Company is of considerable value although it does not give absolute results, that is, it does not give the amount of fibre stress to which the piece is subjected. During the war, the electric welding committee of the Emergency Fleet Corporation designed and built a machine for testing welds up to ¾-inch thick and 8-inch wide in which the fibre stress could be measured. The idea being to test large sections of welds. This machine has not yet been used.





Figs. 13 and 14.—Visible Defects in Oxy-Acetylene Weld Before and After Straining.

Fig. 14.

The ordinary machine for determining the resistance to alternating stress uses a rather small test piece about ⅜ by 2 inches in section which is vibrated back and forth at about a one-thousand alternations per minute. Another machine that will give considerable information is that designed by Mr. F. M. Farmer of the Electrical Testing Laboratories in New York. The test piece is round and is rotated under load. In both these latter cases, the fibre stress can be accurately determined, and this being known, the number of alternations or revolutions is the measure of the resistance of the piece. The difficulty with these two methods of tests is that the pieces are very small so that a small defect may cause the piece to break long before a larger piece would, or before a full sized weld would show any evidence of strain.

A great deal may be learned from the appearance of a weld. It is difficult to describe the appearance of good welds but after they have been seen a number of times, an inspector can readily say whether the operator knows what he is doing. In gas welding, I would not accept a ripple weld in heavy material nor one which was narrower than about 2½ times the thickness of the sheet, because I have never seen a weld having these appearances that was properly welded. The appearance of properly made electric welds has been well described by Mr. Escholtz of the Westinghouse Company and has been published in several of the trade journals. The appearance in a gas weld of porosities on top, indicates that the metal has been overheated, and the same thing is true in an electric weld. Inasmuch as I believe that the serious defects in welds are caused by oxides, it would appear wise in the case of gas welding to use no larger tip than is necessary to produce thorough fusion. This means that the catalogue speeds of welding are impossible if good welds are desired. The same thing is true of electric welds. The reason is that at the high temperatures of the steel caused by too large a tip or too heavy a current, the metal becomes overheated, and in that condition combines more readily with the oxygen of the air or with any excess oxygen in the torch flame, and produces oxides which are readily dissolved by the melted metal. As the metal cools down, these oxides are rejected in large part and pass to the grain boundaries, as do other impurities, so that it is perfectly natural that material which has been seriously overheated should be more brittle and weaker than the material which has been properly melted. In conclusion, I have found in a number of cases that very great improvements in the quality of the work were made by using regularly the bending test above described and by carefully instructing the welders until they were able to make welds that would meet this test with unfailing regularity.

AMERICAN WELDING SOCIETY STANDARDS FOR TESTING WELDS

The Committee on Standard Tests for Welds recommends three separate standards as follows: shop standard; commercial standard and research standard.

Shop Standard

Bending test only.

Commercial Standard

(a) Bending test
(b) Tensile test

Note: It is probable that eventually it will be desirable to include a fatigue test when a method is standardize which will be suitable for commercial application.

Research Standard

A. Tests of base or parent metal

1. Chemical analysis. To include carbon manganese, silicon, phosphorus and sulphur
2. Mechanical Tests.
   (a) Tensile. To include yield point, ultimate strength, total elongation and reduction of area.
   (b) Bending
   (c) Fatigue
3. Metallographic. Photomicrographs at 100 diameters.

B. Test of Weld

1. Mechanical tests
(a) Tensile. To include yield point, ultimate strength, total elongation and reduction of area.
(b) Bending
(c) Fatigue
(d) Impact

2. Metallographic. Photomicrographs at 100 and 500 diameters respectively at (a) the junction between the base metal, and the filled-in metal, (b) the base metal adjacent to the junction, (c) the center of the filled-in metal.

C. Tests of filled-in metal

1. Chemical analysis. To include carbon, manganese, silicon, phosphorus and sulphur.

2. Mechanical tests. Standard round specimens to be prepared from ingots deposited in a base-metal mould of such dimensions that normal cooling conditions will be approximated.
(a) Tensile. To include yield point, ultimate strength, total elongation and reduction of area.
(b) Bending
(c) Fatigue

3. Metallographic. Photomicrographs at 100 and 500 diameters respectively.

Standard Procedures for Mechanical Tests

1. Preparation of Test Welds

No detailed instructions for the preparation of test welds can be given as the dimensions, materials, etc. will depend upon the purpose for which the weld is being made. The test weld should, however, duplicate as nearly as practicable, the commercial welds which it represents and should preferably be of such a size as to permit preparations of enough specimens from the one test weld to make all of the mechanical tests which are to be made.

When the test weld is made with material in sheet or plate form, the longest axis of the test specimen should in general, be parallel to the direction of rolling.

2. General Procedure

(a) Wherever applicable, the standard procedure of the American Society for Testing Materials as given in the A. S. T. M. for 1918 (serial designation E-1-18) shall be followed.

(b) Three duplicate specimens shall be tested in any one test and the average taken as the value of the property determined by this test.

3. Tensile Tests,—Base Metal

(A) Test Specimens

(a) Sheet or plate material. The test specimen for sheet materials is shown in Fig. 1. The thickness of the specimen may be any that is desired, but a thickness exceeding ¾ inch would require a testing machine in excess of 100.000 lb. capacity. If the specimen is cut from standard sheet material, it is usually not necessary to machine the 1.5 inch faces of the specimen.

(b) Cast Material. The test specimen for cast or brittle materials is indicated in Fig. 2*. It is particularly important to use swivel specimen holders when testing such specimens in order to entirely eliminate undesirable stresses.

(B) Test Results to be Recorded

(a) Ultimate Strength. Unit stress (lb. per sq. in.) computed from the area of the original section.

(b) Yield Point. Unit stress (lb. per sq. in.) at which marked increase in deformation of the specimen occurs without increase of load as indicated by a sudden dropping of the beam of the testing machine or by a sudden increase of the rate of elongation as shown by dividers.

**The diameter of this specimen may be 0.505 inch if desired. This diameter gives an area of exactly 0.200 square inch.*

(c) Contraction of Area. Expressed in per cent of the original area.

(d) Appearance of Fracture. The appearance of the fracture as determined with the aid of a low power magnifying glass (such as jewellers use) should be recorded. The characteristics described by the following nomenclature should be covered indicating as far as possible the per cent of the total area which is involved. For example, "10 per cent not welded" would signify that approximately 10 per cent of the total area of cross section at the fracture is exposed base metal—that is, not welded.

Spongy: Full of small cavities; the structure resembles that of a sponge; porous.

Slag inclusions: Foreign matter entrapped in the weld.

Gas pockets: Small or large cavities more or less isolated (i. e., not of a regular spongy structure.)

Not welded: Exposure of any portion of the surface of the base metal indicating imperfect fusion between the base metal and the filling metal.

Laps: Imperfect fusion between adjacent portions or between successive layers of filling metal.

(The recording of the following data is optional.)

(e) Proportionality Limit. Unit stress (lb. per sq. in:) at which the deformation ceases to be directly proportional to the load.

Any type of extensometer may be used in precise work the deformations of two opposite elements of the specimen, preferably on the edges, should be obtained. For ordinary purposes deformations in only one element of the specimen need be measured, but in that case the gauge marks should be on the center of the line of the 1.5-inch side.

The gauge length may be either 2 or 8 inches.

(f) Modulus of Elasticity. Unit stress (lb. per sq. in.) computed from data obtained from a specimen having an 8-inch gauge length; measurements to be taken on two opposite elements, one on each edge of the specimen.

(g) Total Elongation. Gauge marks shall be laid off every inch along a line at the center of one of the 1.5-inch faces of the specimen before placing in the testing machine and the total elongation in every inch after rupture recorded. The total elongation in the 1-inch, 2-inch and 8-inch (if any) length which included the break shall be reported.

4. Tensile Tests, Weld Metal

A. Test Specimens

The shape and dimensions of the test specimens are shown in Fig. 2. It shall be prepared from a bar of **weld metal**, ¾ by 1 by 11 inches. This bar shall be formed entirely by depositing filling metal in an open box of the shape shown in Fig. 3, employing exactly the same method used in making the corresponding test weld. For metal electrodes this box shall consist of a copper plate ½ inch thick, upon which is secured a frame of steel bars, ¾ inch square. The parts of the box were secured in any convenient manner. The copper plate, during this operation shall rest upon a steel plate. After the bar is formed, the copper plate and the frame may be removed by any suitable machining operation.

For gas welding, the copper plate should be replaced by a steel plate. For thermit, a box of suitable refractory material should be used.

(B) Test Results to be Recorded

These shall be the same as those prescribed in Section V, 3-D (base metal) except those involving an 8-inch gauge

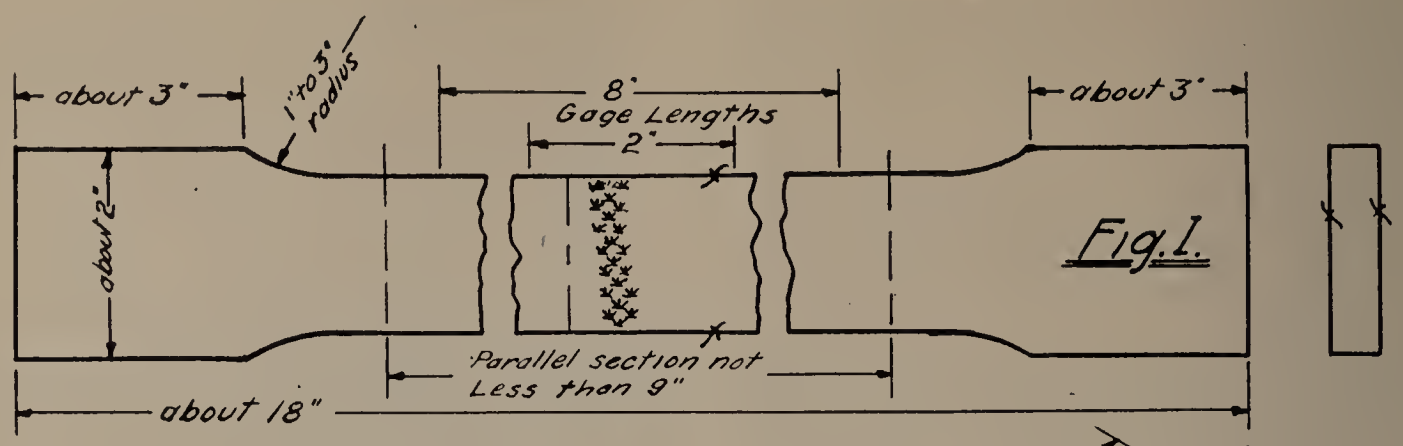


Fig. 1.

Fig. 2.
Finish all over.

The gage lengths, Parallel Portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the Testing Machine.

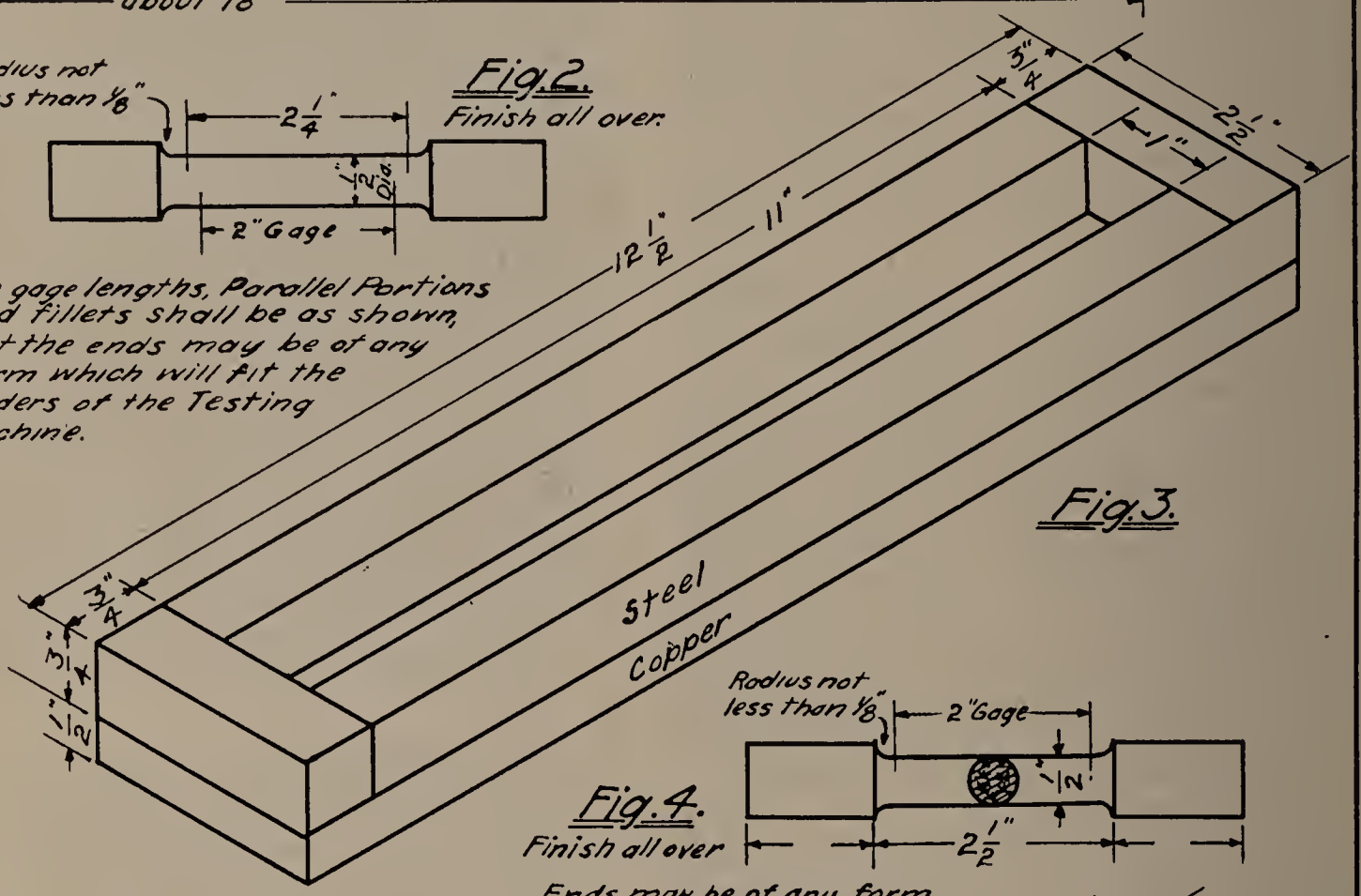


Fig. 3.

Fig. 4.
Finish all over
Ends may be of any form suitable for Testing Machine

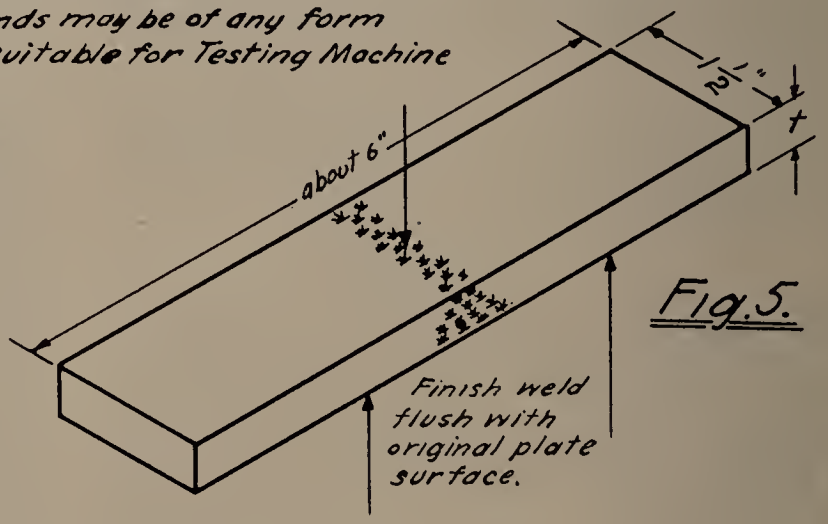


Fig. 5.

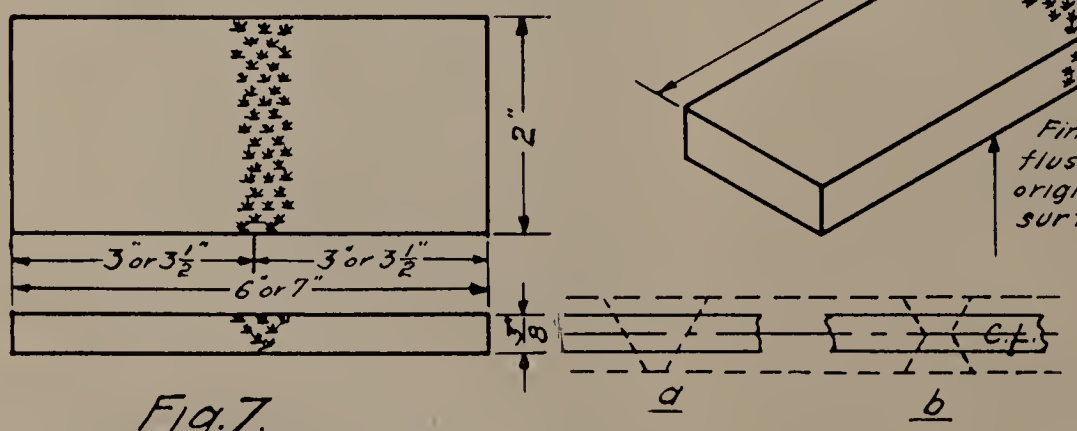


Fig. 7.
Finish and polish all over except ends.

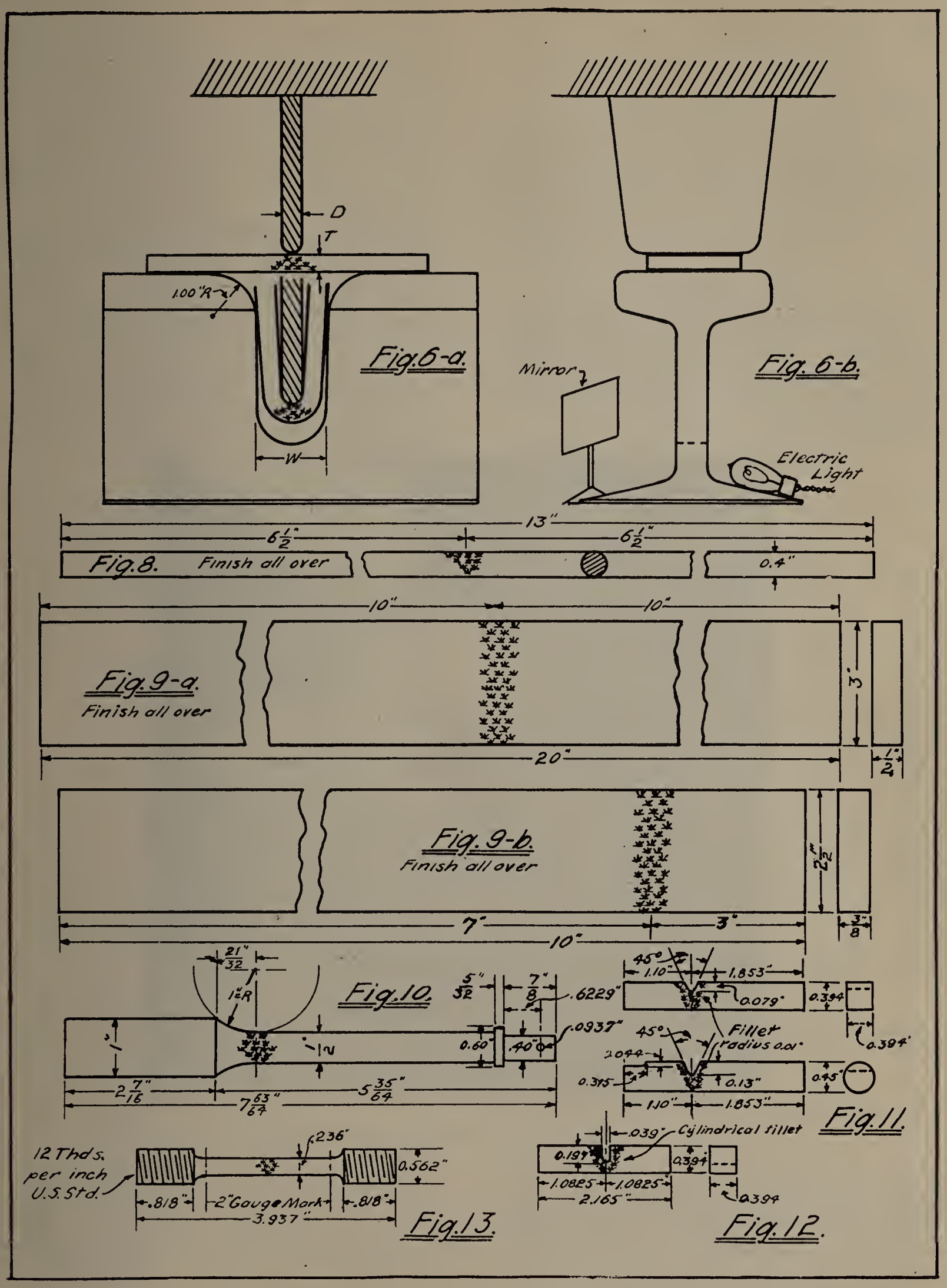
length. If, however, the modulus of elasticity is desired, a specimen similar to that shown in Fig. 2. with a gauge length of 8 in. shall be employed.

5. Tensile Tests, Weld

(A) Test Specimens

The shape and dimensions of the test specimen are shown in Fig. 1 with the weld at the center. If the material is cast or brittle, the specimen shown in Fig. 2 shall be used with the weld located at the center.

It is especially necessary that the 1.5 inch sides of the specimens be machined, particularly if the two pieces of base metal are offset or if they form an angle at the weld. Tests made in the latter case, where the specimens are not machined, are not reliable. Furthermore, care must be taken that specimens having the latter defects are not "straightened" before being machined because such treatment is likely to materially



decrease the strength of the weld. A roughing cut in a planer or shaper which will just "close up" the surfaces of the specimen is sufficient.

(B) Test Results to be Recorded

The requirements for test results given in Section V, 3-B (base metal) shall be followed.

6. Bending Tests, Base Metal, Weld Metal and Weld

(A) Test Specimens

(a) **Base Metal and Weld.** The shape and dimensions of the specimen are shown in Fig. 5.

In the case of welds in flat rolled material, the surface of the weld shall be machined substantially flush with the surface of the specimen unless the specimen is bent or offset, in which it shall be machined all over. Cast and other irregular specimens

shall be machined all over. It is essential that the edges of all specimens be machined to remove material in a condition likely to cause premature failure.

The thickness, t, of a weld specimen shall be as nearly that of the base metal as possible.

(b) **Weld Metal.** A specimen may be prepared from a bar of weld metal prepared as prescribed for tensile tests (Section V, 4-A). The box, Fig. 3, shall however have a width of 1.75 inches and the thickness, t, of the specimen shall be that of the test weld. These specimens shall be machined all over.

(B) Apparatus

In order to load the specimens so that as large a part of the bend as possible shall occur in the weld metal, the special fixture outlined in Fig. 6a and 6b shall be used. It is most conveniently used with any standard universal testing machine but may be operated by any other convenient mechanical means.

tached to the under side of the moving head of the testing machine. Upon the platform shall be fastened two blocks having machined top surfaces and polished corners of radius, R, of 1.00 inch. These blocks shall be separated by a distance, W, equal to D plus 2T plus ⅛ inch. A lubricant of lard oil and graphite or similar compound shall be used on these surfaces.

Two specimens shall be tested. The load shall be applied at the center of the weld, —in one specimen to the open side of the "V" and in the other specimen to the closed side.

The rate of application of the load shall not exceed that at which the beam can be kept balanced at all times or a maximum of 2 inches per minute.

The angle through which the specimen is bent may be measured by any convenient method. The following method is described as a matter of information.

A piece of paper is held firmly against the edge of the specimen when it is in place on the testing fixture and a line drawn on the paper along a corner of the specimen, thus outlining the shape of the specimen so

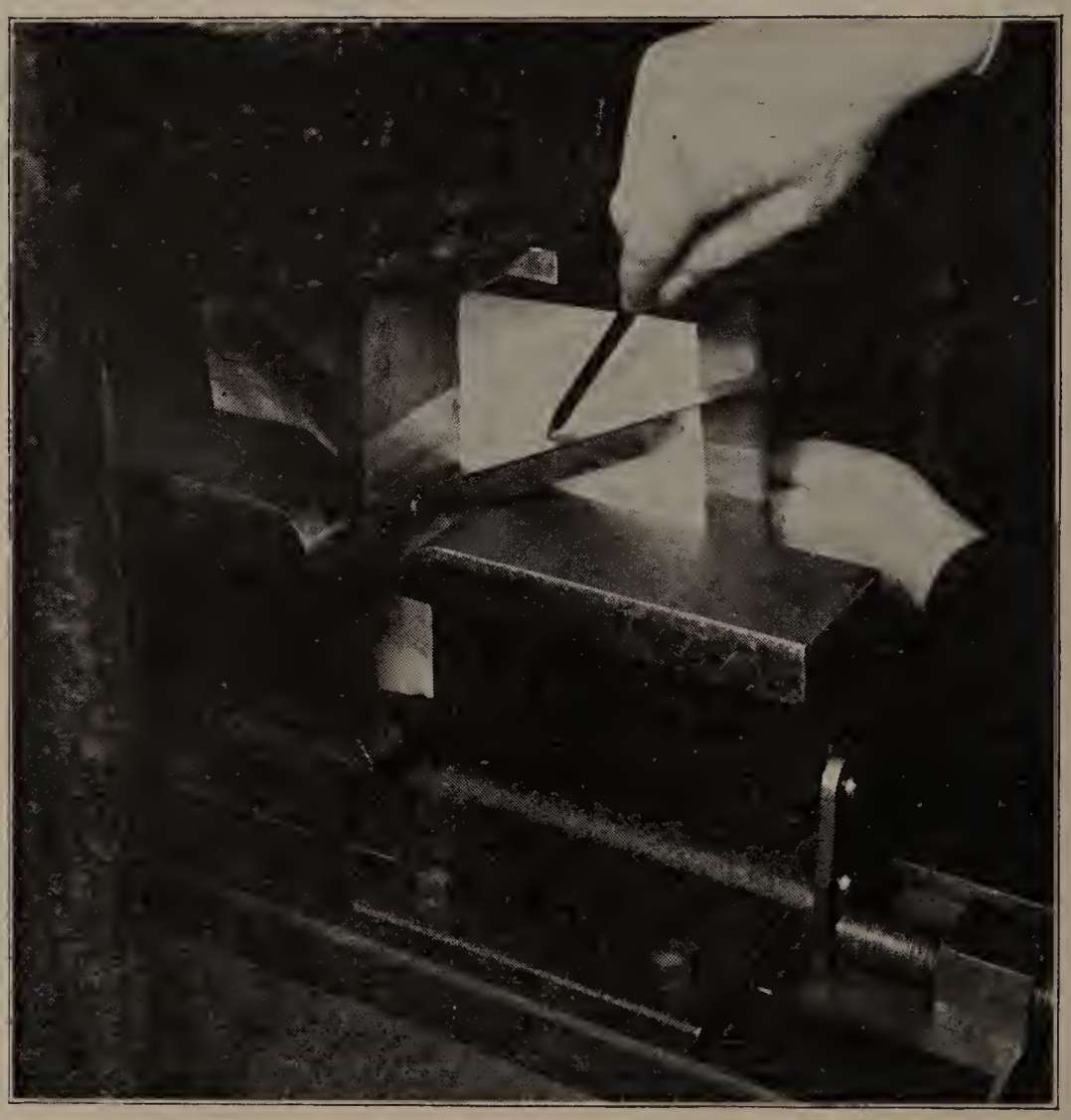


Fig. 14. Measuring Angle in Bending Test.

The cylindrical surface, D, (Fig. 6a) about which the specimen is bent shall conform to the requirements of the American Society for Testing Materials for bending tests of the base metal*. This piece is at-

far as bending is concerned. A line is drawn before loading and after failure occurs. The change in the angle in the two lines as determined with a draftsman's protractor is the angle through which the specimen had been bent at failure. See Fig. 14.

(C) Tests Results to be Recorded

(a) The total angle through which the specimen has been bent when the first crack appears upon the convex surface (that is, the sum of the angles through which the two halves were bent). To be measured without removing the load.

Note: An electric light and mirror will assist in observing this surface as indicated in Fig. 6b.

(b) The load on the specimen at which the first crack occurs.

**For ship-plate steel* (58000-68000 *lb. per sq. in. tensile strength*), *it is "The test specimen shall bend cold through* 180 *degrees without cracking on the outside of the bent portion, as follows: For material* ¾ *in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over* ¾ *in. to and including* 1¼ *in. in thickness around a pin the diameter of which is equal to* 1½ *times the thickness of the specimen; and for material over* 1¼ *in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.*

7. Fatigue Tests, Base Metal, Weld Metal and Weld.

There is no generally accepted unit or standard of comparison for fatigue tests so that the results given by the several machines which have been developed for such tests are not directly comparable. It is not practicable at the present time to recommend the use of any particular type of machine and consequently test specimens are shown for all of the more common types.

Although in general the results of fatigue tests are of maximum value only when compared with similar results obtained on the same machine, it is assumed that tests will be made on the base metal so that the results of tests on welds and weld metal can also be stated in terms of the results of tests of base metal. It is hoped that this will permit direct comparisons between tests made with different types of machines.

(A) Machines and Test Specimens

(a) **General.** For tests of weld metal it will be necessary to form a suitable bar in a box similar to Fig. 3 and having the proper dimensions.

Fatigue tests specimens should in general be machined all over (except the ends) and the surface carefully polished (preferably with the polishing marks parallel to the longest axis of the specimen). No. 1 Manning emery cloth or paper or its equivalent will produce a satisfactory surface.

Provided the specimens are prepared from a test weld or other material of greater thickness than the specimen, an equal amount shall be removed from both sides so that the specimen shall represent the material at the middle as indicated at an angle Fig. 7.

(b) **Upton-Lewis Improved Machine.** This machine puts a bending load on the specimen which is reversed during each revolution of the machine.

Specimen shown in Fig. 7. The distance between the jaws of the machine shall be ½ inch. If the specimen is a weld specimen, the jaws shall be equidistant from the center of the weld metal.

(c) **Farmer Machine.** This machine was designed specially for testing weld specimens. It tests the specimen as a simple rotating beam with free supports at the ends and two equal loads on a section at the middle. Specimen shown in Fig. 8. If the specimen is a weld specimen, the weld metal shall be at the center.

(d) **Strohmenger Reverse Torsional Machine.** Comparative results only can be obtained as there is no means of determining the stress. This machine loads the specimen in torsion which is reversed for each revolution of the machine.

Specimen shown in Fig. 9a.

(e) **Strohmenger Bending and Impact Machine.** Comparative results only. The machine strikes the specimen which is held as a cantilever beam, bends it and releases it. This operation is repeated upon the other side of the machine. The weld, if any, is placed just outside the clamp in such a position as to develop the maximum stress in the specimen.

The specimen is shown in Fig. 9b.

(f) **Moore Machine.** This machine was designed for the Bureau of Standards for testing large size specimens of joints, both welded and riveted. It loads the specimen as a simple beam at the third point and the direction of loading is reversed for each revolution of the machine.

Specimens. Any thickness not exceeding about 1 inch, width 8 inches, length 32 inches. If the specimen is a weld specimen, the weld metal shall be at the middle of the length of the specimen.

(g) **White-Souther Machine.** This machine loads each end of a rotating specimen as a cantilever beam. It is then rotated.

The specimen is shown in Fig. 10.

(B) Test Results to be Recorded

(a) Number of cycles of the stress required to cause failure. A cycle is the period of time at the end of which the repetition of the variations of stress is begun.

(b) The stress developed in the specimen (if possible).

See "Etching."

Testing Electric Arc Welds

To determine roughly whether the arc is properly adjusted run a bead on a sample and test by chipping as follows:

(1) Chip off bead and examine metal.

(2) If in chipping off bead it comes loose, machine is adjusted for too little heat or penetration.

(3) If bead is porous or overlaps, too much heat is being produced at the arc.

(4) If bead chips off flush and clean, and no porous spots show, and metal is not burned, the adjustment is correct.

Test Specimen

A prepared piece on which a mechanical test is to be made.

Test Weld

A sample of welding which has been performed under known conditions and upon which mechanical tests are to be made.

"Thermalene"

Trade name for acetylene generators, torches, etc. Made by The Thermalene Co., 413 City Bank Bldg., Kankakee, Ill.

"Thermit"

A mixture of aluminum and iron oxide which when ignited by means of special ignition powder produced on reaction a superheated liquid steel and slag (Aluminum Oxide) at approximately 5000° F. This Thermit Steel is sufficiently hot to melt and dissolve any metal with which it comes in contact and amalgamates with it to form a solid homogeneous mass when cooled. For this reason the Thermit reaction is especially adapted for the welding of heavy steel and cast iron sections, such as are used in locomotive, marine, crankshaft and steel mill repairs, also for pipe welding and rail welding.

Thermit is made by the Metal & Thermit Corporation, 120 Broadway, New York City. See chapter on "Thermit Welding," also Table of Contents, Catalog Section.

"Thomson"

Trade name for electric resistance welding machines. Made by Thomson Spot Welder Co., Lynn, Mass.

Thomson Process

See "Butt Welding" in chapter on "Electric Resistance Welding."

Tinning

The act of coating another metal with tin and also a term sometimes used to describe the coating of another metal, such as the coating of a low-carbon shank with added metal, before welding in a high speed tip.

"Tinol"

Trade name for a soldering paste for cast iron. Made by Hess & Son, Philadelphia, Pa.

Tip

That part of the torch from which the gas is discharged. Sometimes called "nozzle."

Tip Welding

Welding high carbon steel tips to low carbon steel shanks. See "High Speed Steel" in this section, also under "Butt Welding" and "Spot Welding" in chapter on "Electric Resistance Welding."

"Titan"

Trade name for iron and steel welding rods. Formerly made by Davis-Bournon-

ville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Tobin"

Trade name for bronze welding rods. Made by Anaconda Copper Mining Co., Torrington, Conn.

"Toleman"

Trade name for welding and cutting torches, accessories and supplies. Made by Toleman Mfg. Co., Boston, Mass.

"Tombac"

Trade name for a flux for brazing alloy steels and copper. Made by Morey Flux and Chemical Co., Parkesburg, Chester County, Pa. See Table of Contents, Catalog Section.

Torch

A tool or an instrument used for welding or cutting. Such torches burn a combination of some of the many high temperature gases. Torches are also used for preheating, such torches burning city gas, kerosene, etc.

Torch Classification

Welding torches are classified in relation to the pressure of the acetylene. Low pressure torches (injector) are those using the acetylene under a pressure of one pound or less and the velocity of the oxygen is taken advantage of to aspirate or suck a sufficient volume of acetylene to form the neutral welding flame.

Medium pressure torches (sometimes called positive pressure) are those using the acetylene under some pressure, up to as high as fifteen pounds, and the oxygen under a still greater pressure, usually from two to three times as great as the acetylene.

In both these types (low pressure and medium pressure) the mixing chamber is so proportioned that the areas of the acetylene passages are much greater than that of the oxygen entrance which acts as an injector or partial injector.

Equal pressure torches (sometimes called balanced pressure) are those torches using both gases at equal pressures.

Higher acetylene pressure torches are a recent development and the term is somewhat misleading as the pressures used for the acetylene are very rarely any higher than those used by the positive pressure torches and sometimes less, but the oxygen pressure is materially reduced, and in fact below that of the acetylene.

In this type of torch the areas of the mixing chamber are so proportioned relatively that the acetylene enters the mixing chamber at a pressure slightly greater than the oxygen.

Torch Head

That part of the torch which holds the tip.

Torch Tube

That part of the torch which forms the tube connecting the torch head and handle.

"Torchweld"

Trade name for welding and cutting torches and regulators. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Torit"

Trade name for acetylene torch for radiator repairing, soldering, etc. Made by St. Paul Welding & Mfg. Co., St. Paul, Minn. Distributed by Bastian-Blessing Co., Austin Ave. & La Salle St., Chicago, Ill. See Table of Contents, Catalog Section.

Track Welding

The process of building up frogs and switch points is described under "Frog Points" and "Manganese Steel." Another important track repair is building up rail ends at the joints. The rail is heated to a cherry red on the running edge, and this edge is pounded in to make the rail even, like a new one. Then the top is heated the same way and the surface or skin broken with a torch, and all the old metal of the chipped part either run out or worked in, taking care that no holes are covered up. New metal is then applied, using a high carbon steel rod and welding right over the joint provided the crack is not more than ⅛ of an inch.

When enough metal has been added, smooth over with the torch, using a slightly carbonizing flame, and then hammer fairly smooth with a machinist's hammer. While the weld is still red hot finish the smoothing process with a blacksmith's flattening tool and an 8-pound sledge. Heat again to red hot right across the joint and cut

Below—Battered Rail End.
Above—Same Rail After Welding.

straight across with a hot cut chisel. Be sure that this cut is made exactly over the original joint. After cutting, heat the parts on both sides red hot and use the flatter once more, starting on the running side of the rail, coming up and over the top, down on the outside, and back again. In case the rails are more than 3/16-inch apart, weld each rail end separately, using the same method as when welding straight across. Use a straight edge or carpenter's square to keep the surface even. Be sure the joints are tamped up level before starting.

Tractor Wheels

Repairs commonly found necessary in large tractor wheels are broken hubs and spokes. Very often when a piece is broken from the hub it becomes lost so that it is necessary to build in an entirely new part. In this case roll the wheel around until the broken part of the hub is on top so that the weld will be made in a horizontal posi-

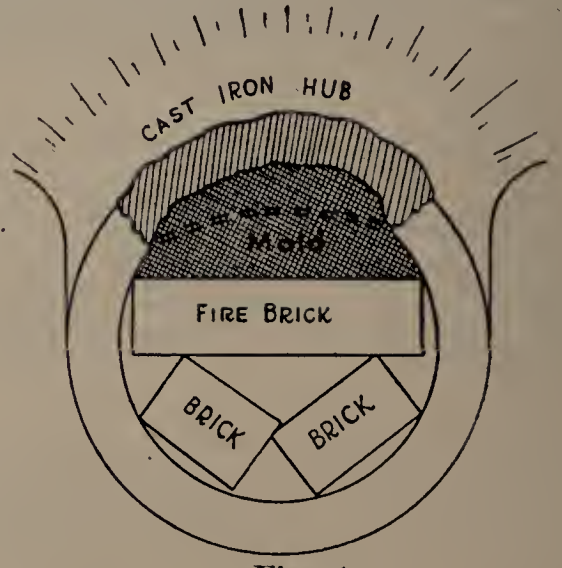


Fig. 1.

tion. Insert fire brick as a support for mold, and make a mold of carbon paste. Scrape all the surplus compound off the edge of the break and play the welding torch lightly over the mold to help it set.

Use a good sized welding flame on the metal back of the break and when it becomes red, start adding the filler rod, fusing it to the edge. Take care that the flame strikes only the metal and not the mold.

If a spoke is broken some provision has to be made for contraction. The easiest way to take care of this problem is to bend the spokes outward a little before starting to weld. They will straighten up and take care of the contraction as they cool.

Fordson Tractor wheels are built with steel spokes chilled into a cast iron hub and riveted at the outer end to the rim. These spokes frequently crystallize about ¼ inch from the hub, and it is not unusual to run across wheels of this type with nearly all the spokes either broken or loose in the hub. The usual break is one or more spokes at the point where crystallization usually occurs.

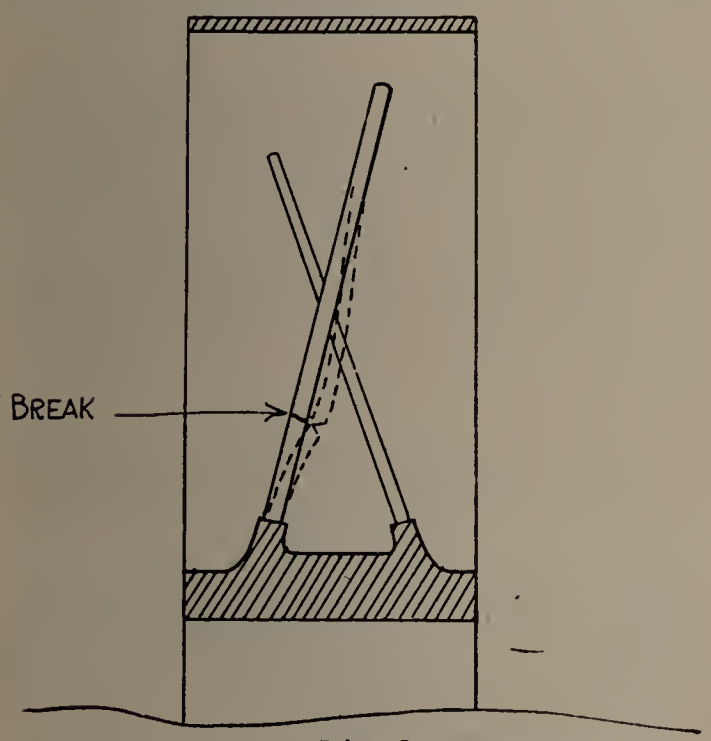


Fig. 2.

The most successful way to repair a wheel in this condition is as follows:

Cut the spokes on one side of the wheel loose at the rim (point 1) by cutting the head off of the rivets and backing them out. Then weld all the spokes on this side

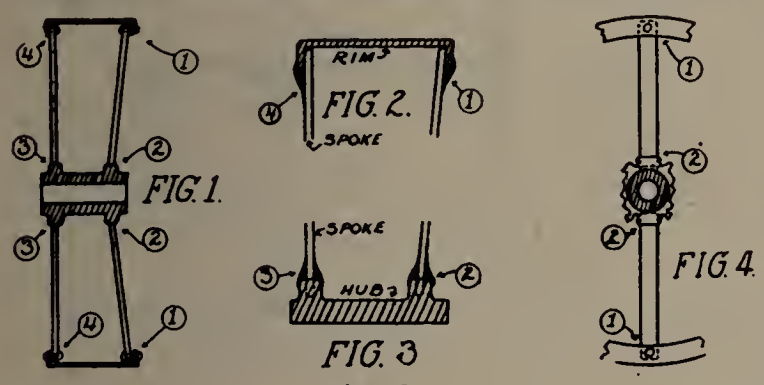


Fig. 3.

of the wheel in the hub (point 2), using cast rods. Make the weld about one inch wide and sloping to the outer edge, or sloping up the spoke.

After completing weld on outer side of hub (figure 3: point 2), repeat the operation on the inside. In the same manner weld all spokes to the hub on the opposite side of the wheel (figure 3: point 3). Next free all the spokes still riveted on other side of the wheel (figure 1: point 4). Now weld all the spokes to the rim on the side which was first cut loose, welding as shown (figure 2: point 1) using steel filler rods.

When all spokes on this side of the wheel are welded straighten wheel and weld spokes shown on other side (figure 2: point 4). Figures No. 1 and 4 show the usual construction of the wheel before welding. In cases where a broken spoke is loose in the hub remove spoke and replace with a new spoke of corresponding material.

Trapping the Weld

Flowing together of the metal in the joint above and below the flux so that the flux cannot be entirely burnt out.

"Tripure"

Trade name for water stills for electrolytic oxygen plants. Made by Standard Water Systems Co. of New Jersey, Hampton, N. J.

Tube Welding

Light welded tubing can be produced on special tube welding machinery, using a multiple flame machine torch. For all practical purposes this tubing will be as good as seamless tubing, and much cheaper. The equipment required depends on the material to be used and the fabrication to which the tubing is to be subjected before leaving the tube shop. Raw material may be either commercial steel sheets or rolled strips. One size of welded tubing can be made to produce several sizes by drawing through reducing dies. Square, rectangular, hexagonal or oval tubes can be produced by drawing welded tubing over the proper dies. See "Automatic Welding Machines" in chapter on "Oxy-Acetylene Welding."

A form of production welding commonly encountered in practice is the fabrication of a variety of small structures from steel tubing. Jigs are readily constructed by welding together pieces of channel iron in the proper shape as described under "jigs." A good deal of this work involves the making of tubular parts which are not required to

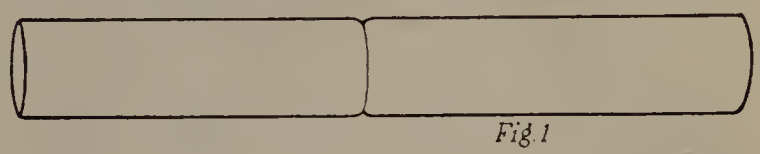


Fig. 1

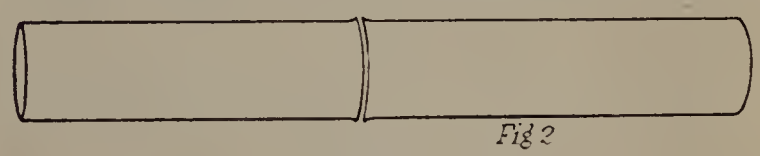


Fig. 2

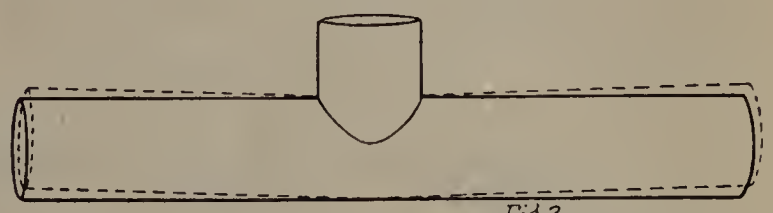


Fig. 3

carry gases or liquids (such as metal furniture), therefore, the welder needs only a little practice to turn out a smooth appearing joint which will not call for much filing before the final finishing process. On some jobs, however, a more perfect joint is necessary, and cannot be obtained without making provision for contraction effects. Practically all of the contraction problem encountered in tube welding is illustrated in Fig. 1. This shows what happens when two pieces of tubing are simply butted together

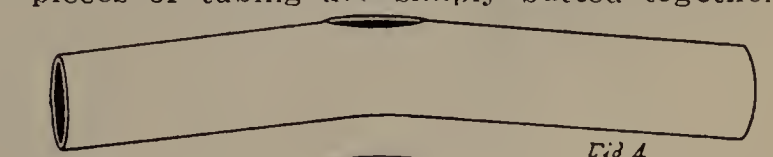


Fig. 4

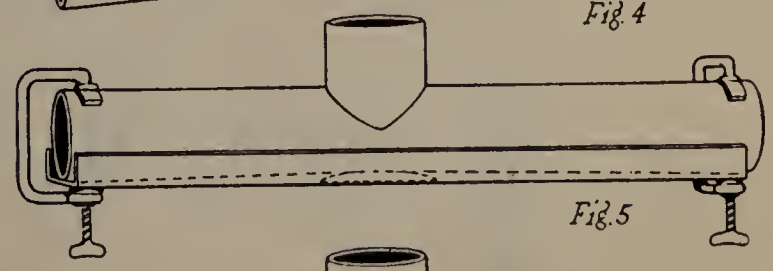


Fig. 5

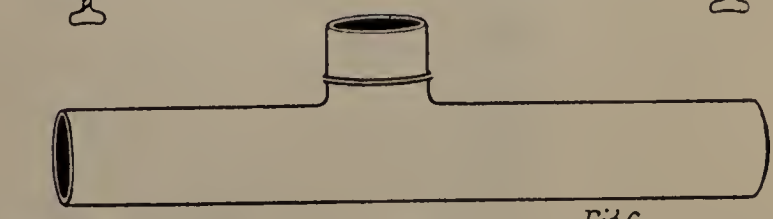


Fig. 6

and welded. The molten metal contracts as it cools and draws the abutting ends in-

ward, decreasing the diameter, and making an unsightly joint. Fig. 2 shows one of the most satisfactory ways employed to avoid such results, that of bending the abutting ends slightly outward before welding, so that the contraction will pull the line of weld in even with the sides of the tubes.

Tee welds made in tubing according to the design shown in Fig. 3 will result in a distortion such as indicated by the dotted lines. A preliminary distortion such as shown in Fig. 4 will be taken up by contraction of the joint and the result will be approximately square. A jig for bringing about this preliminary distortion is shown in Fig. 5. A better design for tee welds is shown in Fig. 6, with the flanging of the long piece slightly exaggerated. It is important to overcome as much of the difficulty as possible in the design of the joint.

Tungsten

A metallic element used in the manufacture of alloy steel, particularly high speed steel, where it is required to have hardness retained at high temperatures.

—U—

"Union"

Trade name for carbide of calcium. Made by Union Carbide Sales Co., Carbide and Carbon Bldg., New York, N. Y. See Table of Contents. Catalog Section.

"Universal"

Trade name for bronze welding rods, brass and bronze fluxes. Made by Torchweld Equipment Co., Fulton and Carpenter Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Universal"

Trade name for oxygen and hydrogen gases, welding and cutting supplies, and Oxygen and Hydrogen Generators. Made by Universal Oxygen Co., Sheboygan, Wis. See Table of Contents, Catalog Section.

"Universal"

Trade name for electrode holders. Made by Roy O. Williams, 946 Livingston Ave., Columbus, Ohio.

"Unoxco"

Trade name for oxy-acetylene welding and cutting apparatus. Made by Universal Oxygen Co., Sheboygan Wis. See Table of Contents, Catalog Section.

Upset Weld

A form of electric butt-welding, used in all cases where the weld is to be hammered, using the heat generated in welding. The amount of metal generally left extending from the jaws for making an upset weld in wrought iron or steel is about 1¼ times the diameter of the work. The upset weld is also used in some cases on small rods or rings where it is not necessary to have a uniform thickness of stock. See "Butt Welding" in chapter on "Electric Resistance Welding."

"U. S."

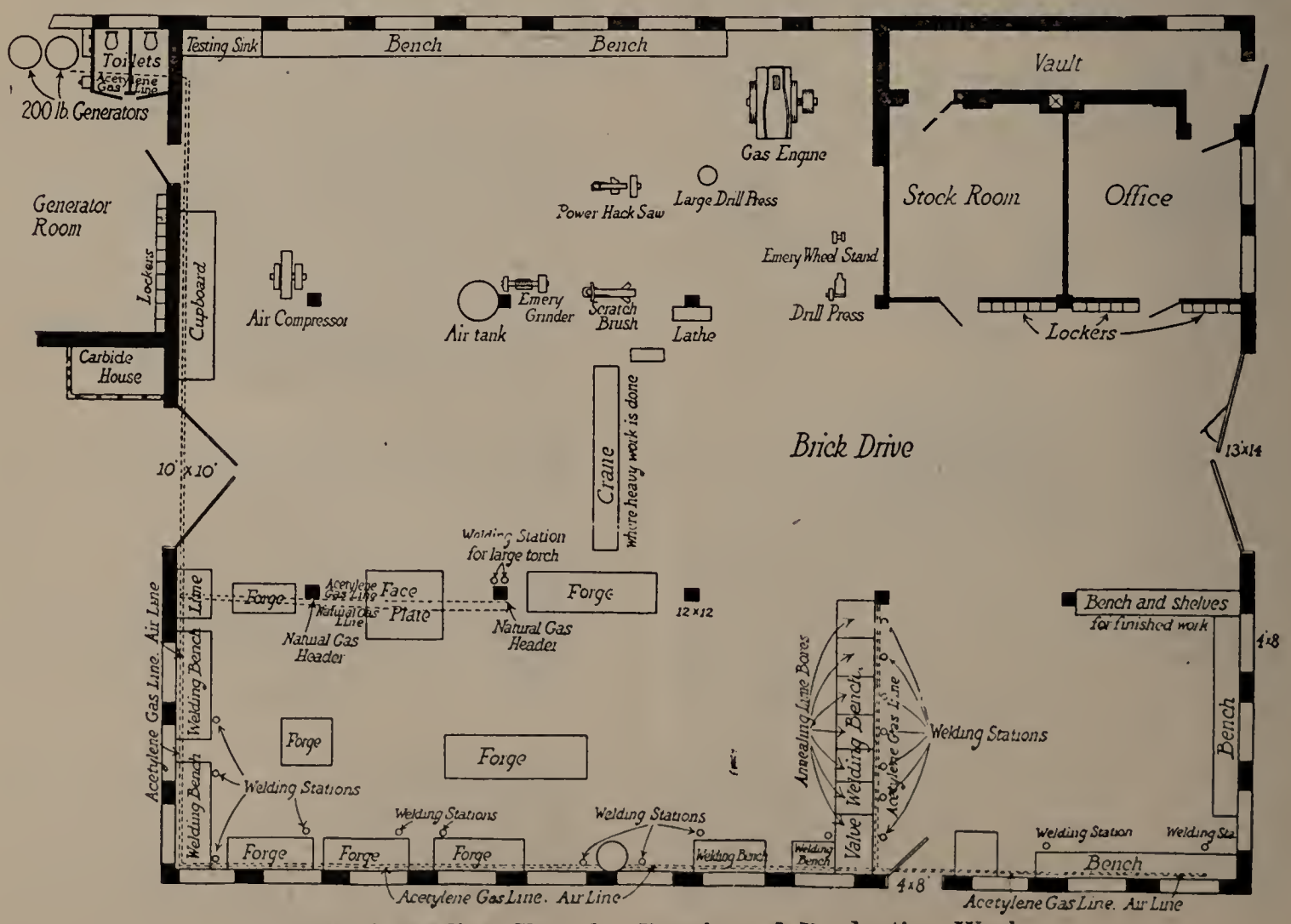
Trade name for gauges. Made by U. S. Gauge Co., 44 Beaver St., New York, N. Y. See Table of Contents, Catalog Section.

"U. S."

Trade name for welding, cutting, lead burning and carbon removing equipment, acetylene generators, preheating torches, accessories and supplies. Made by the United States Welding Co., 120 North 1st Street, Minneapolis, Minn. See Table of Contents, Catalog Section.

"U. S. L."

Trade name for motor generator arc welding outfits. Made by U. S. Light & Heat Corp., Niagara Falls, N. Y.



Layout of Welding Shop for Repair and Production Work.

—V—

Valve Guides

Building up old valve guides which are so worn as to make bushing impossible, is a more difficult job than building on an entirely new guide. Cut the old one off close to the cylinder and make a new boss using carbon paste or carbon block if necessary.

Valve Seats

Welding new valve seats in cylinder blocks is not a very common practice for the reason that too many times the ultimate cost of the job is greatly over estimated and the cylinder block finds itself in the scrap heap instead of the welding shop. The job can be handled in this maner: First the valve chambers are packed with asbestos mush up to the bottom of the valve seat. Then a round piece of carbon, the size of the hole and ⅛-inch thick is pressed down in the asbestos until the top of it is level with the bottom of the valve seat. This can be done in each valve chamber, but it is preferable to insert a piece of pipe in one of the valve chambers to allow gases to escape. The block is then bricked on the floor and preheated with charcoal until quite rosy. It is covered with a sheet of asbestos paper and the welding then proceeded with, through a slot cut in the sheet directly over the valve holes. The slot is covered in such a manner as to expose one hole at a time. The seats are welded up solid, the piece of carbon forming a bottom for the weld. When all holes are welded, the block is left to cool over night. All the equipment necessary to machine up the job is a fairly accurate drill press. A core plug is screwed into the block for centering the drill which should be the same size as the hole in the valve stem guide. After drilling through the weld a fly-cutter with a pilot long enough to enter the valve stem guide, is used to first face off the top of the weld and then bore same to proper diameter. A valve reseater finishes the job. There should be no trouble in encountering hard spots as these are entirely unnecessary if the weld is made properly.

Vanadium

A metallic element sometimes added to steel to increase its tensile strength.

"Vanadweld"

Trade name for alloyed vanadium welding rod. Made by Steel Sales Corporation, Adams and Jefferson Sts., Chicago, Ill. See Table of Contents, Catalog Section.

"Vanox"

Trade name for vanadium steel rod for acetylene or electric welding. Made by Central Steel & Wire Co., 127 N. Peoria St., Chicago, Ill. See Table of Contents, Catalog Section.

"Van Gleckland"

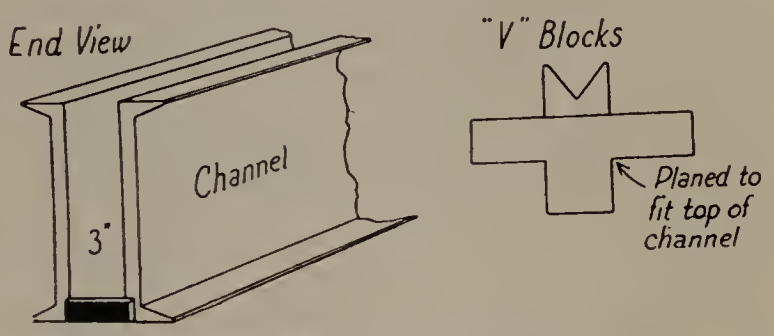
Trade name for semi-portable acetylene generators. Made by Blake Mfg. Co., Mansfield, Pa.

Vee or V

See "Beveling."

V-Block

Castings having a V-shaped notch, used for lining shafts, etc. Small jobs are greatly facilitated by the use of V-blocks which can be handled to good advantage by making a frame for them as shown in the sketch.



Holder for V-Block.

Two pieces of channel iron 40 inches long are set apart three inches and tied together with straps welded on each end and on the bottom. It is not advisable to place too much confidence in this device as a means of preserving alignment while welding. See "Preheating" and "Alignment."

"Victor"

Trade name for welding and cutting torches, accessories, supplies, etc. Made by Victor Oxy-Acetylene Equipment Co., 884 Folsom St., San Francisco, Cal.

"Viking"

Trade name for cast iron and steel welding rods for oxy-acetylene and electric arc welding. Made by Standard Steel and Wire Co., 549 W. Washington St., Chicago, Ill.

Voltex Welding Process

A modification of the Zerener process, using carbon rods containing a small percentage of metallic oxide which is converted into metallic vapor. This vapor increases the size of the arc and to some extent prevents the excessive carbonizing of the work. The process has not been found practial for general work.

"Vulcan"

Trade name for welding and cutting torches. Made by Air Reduction Sales Co., 342 Madison Ave., New York, N. Y. See Table of Contents, Catalog Section.

"Vulcanite"

Trade name for asbestos welding paper. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

—W—

Wabblers
Repairs on worn roll wabblers are not much different from the repair of worn or broken gear teeth, except that it is heavier work, and therefore some extra devices are necessary for success. Reference to the subject "Carbon" will show how molds can be prepared from carbon paste or cut from carbon slabs. It has been recommended that the welder use two forms, one of them being in the shape of one lug and the other including all the lugs, i. e., a duplicate of the cross section of the wabbler. A V-roller for holding the roll while welding will save a great deal of labor and facilitate rapid work. Also, since preheating is so important in welding wabblers, extra care should be exercised in the construction of the preheating furnace. These parts have to work under extremely severe conditions, so the highest possible grade of welding rod should be used, and the workmen should be instructed to use the utmost care to secure perfect fusion and thorough penetration.

"Walloon"
Trade name for welding rods and wire. Made by Apex Steel Corporation, 50 Church St., New York, N. Y.

"Wanamaker"
Trade name for coated electrodes. Made by Transportation Engineering Corporation, 200 Fifth Ave., New York, N. Y.

Warping
To distort or pull out of line or place. See "Preheating."

Washing
Washing the weld is the act of melting the surplus metal on the outer surface of the weld, to obtain a better appearing weld.

Wash Welding
The act of turning a plate over and "wash welding" the reverse side of a weld. Usually resorted to in order to camouflage a poor weld. See "Beveling."

Water Gas
A mixture of carbon monoxide and hydrogen, made by passing steam over red-hot coke. A costly installation used in connection with fire or forge welding.

"Waters"
Trade name for A. C. arc welding transformer. Made by Waters Arc Welding Corporation, 619 Tenth Ave., New York City.

Water Jackets
Cracked water jackets present a problem of welding a complex casting. The most successful way of handling them is to preheat the casting all around the break with a slow fire. This necessitates removing all of the fittings from the casting so that they will not be lost or damaged. Have the break beveled out and the metal on each side of the weld thoroughly clean. If possible, make the weld with the casting still in the fire. If the crack is close to the wall of the cylinder, care must be taken to direct the heat toward the heavier section in order to prevent that section from taking up the heat from the weld itself and thus causing further strains and cracks. The secret of successful work on these complex castings is largely a matter of arranging the preheating fire so that the heavier sections get more heat than the lighter sections.

"Watersweld"
Trade name for electrodes, bare and coated. Made by Waters Arc Welding Corporation, 619 Tenth Ave., New York City.

Water Outlet
The water outlet of an automobile is a rather thin casting and will warp very easily unless some provision is made for the contraction which occurs after welding. They usually crack straight across the casting. The cracks can be repaired by following the directions for cast iron welding, taking the precaution to keep the heat as even as possible and keep it distributed through the entire width of the casting until the welding is completed. It is often recommended that this repair be made by starting at the center and working toward the edges.

Water Pail Forge
See "La Grange-Hoho" process.

Water Seal
A device installed in gas pipe-lines, to prevent backfires to generators, etc.

Watt
Electrical unit of power. It is determined by multiplying the voltage by the amperage. One horsepower is equivalent to 746 watts.

Weaving
In arc welding. A semi-circular motion of the arc terminal to the right and left of the direction of deposition, which serves to increase the width of the deposit, decrease overlap and assist in slag flotation.

Wedges
Wedges or jacks may sometimes displace the preheating fire, if applied properly. See "Preheating."

"Weld-a-Cast"
Trade name for fluxes. Made by Cortland Welding Compound Co., Cortland, N. Y.

"Weldbest"
Trade name for asbestos paper for welding. Made by Asbestos Products Co., 220 S State St., Chicago, Ill.

"Weldco"
Trade name for trucks to hold acetylene and oxygen cylinders. Made by Cave Welding & Mfg. Co., Springfield, Mass.

"Welder's Moulding Compound"
A plastic carbon compound for building moulds, dams, etc. See "Carbon" for suggestions for use. Made by U. S. Welding Co., Minneapolis, Minn. See Table of Contents, Catalog Section.

"Weldine"
Trade name for a flux for electric welding of all metals except aluminum. Made by Krembs & Co., 173 N. Green St., Chicago, Ill.

Weld Metal
Material which has been used in forming a weld. It may consist wholly of base metal or partly of added metal.

Welding Rod
Filling metal used in gas welding.

Welding Rods and Wire
A term used to describe the filler rod, added material, etc. Also sometimes described as "adding material." (See "Beveling".) Such material is, of course, used to fill the "Bevel" or the "V." It should be of a quality and composition to assure a strong union. The proper rod to use depends wholly upon the particular metal to be welded. The proper rod to use and its correct manipulation will be found discussed in the chapters on "Oxy-Acetylene Welding" and "Electric Arc Welding."

AMERICAN WELDING SOCIETY SPECIFICATIONS FOR WELDING RODS AND ELECTRODES

Revised May 1, 1921

General
1. The following specifications prefixed by the letter E are recommended for the purchase of all bare iron and steel electrodes for use in arc welding. The use of each particular type of electrode is specified below.

Scope
2. The electrodes herein specified are recommended as covering the usual railroad, shipyard and industrial requirements as are allowed by authoritative regulating bodies, such as the American Bureau of Shipping, The Interstate Commerce Commission, etc.

Material
3. Material made by the puddling process is not permitted.

Physical Properties

4. Electrodes shall be made of commercially straight wire of uniform homogeneous structure, free from irregularities in surface hardness, segregation, oxides, pipe, seams, etc. Diameter shall not vary more than plus or minus 3 per cent from diameter specified.

Nomenclature

5. The prefix letter E is to indicate that the material is intended for electric arc welding.

Chemical Composition

6. The chemical composition of electrodes shall be within the following limits for uses specified:

Low Carbon Iron or Steel

E-To. 1A

Carbon	not over 0.06 of one per cent
Manganese	not over 0.15 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent
Silicon	not over 0.08 of one per cent

High Carbon Steel

E-No. 1C

Carbon	0.85—1.10 per cent
Manganese	0.30—0.60 of one per cent
Silicon	not over 0.06 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent

Recommended Sizes

7. E-No. 1A and E-No. 1B, $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, $\frac{1}{4}$ in dia.

E-No. 1C, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, $\frac{7}{32}$, $\frac{1}{4}$, $\frac{9}{32}$, $\frac{5}{16}$ inch dia.

Uses

8. E-No. 1A and E-No. 1B—For welding mild steel structural shapes, plates, bars or low carbon steel forging and castings.

E-No. 1C—For welding high carbon steel and worn surfaces where great resistance to abrasive wear is desired and where machining is not necessary, such as rails, frogs, switch points, bearing surfaces, etc.

Surface Finish

9. The surface shall be smooth and free from rust, oil or grease.

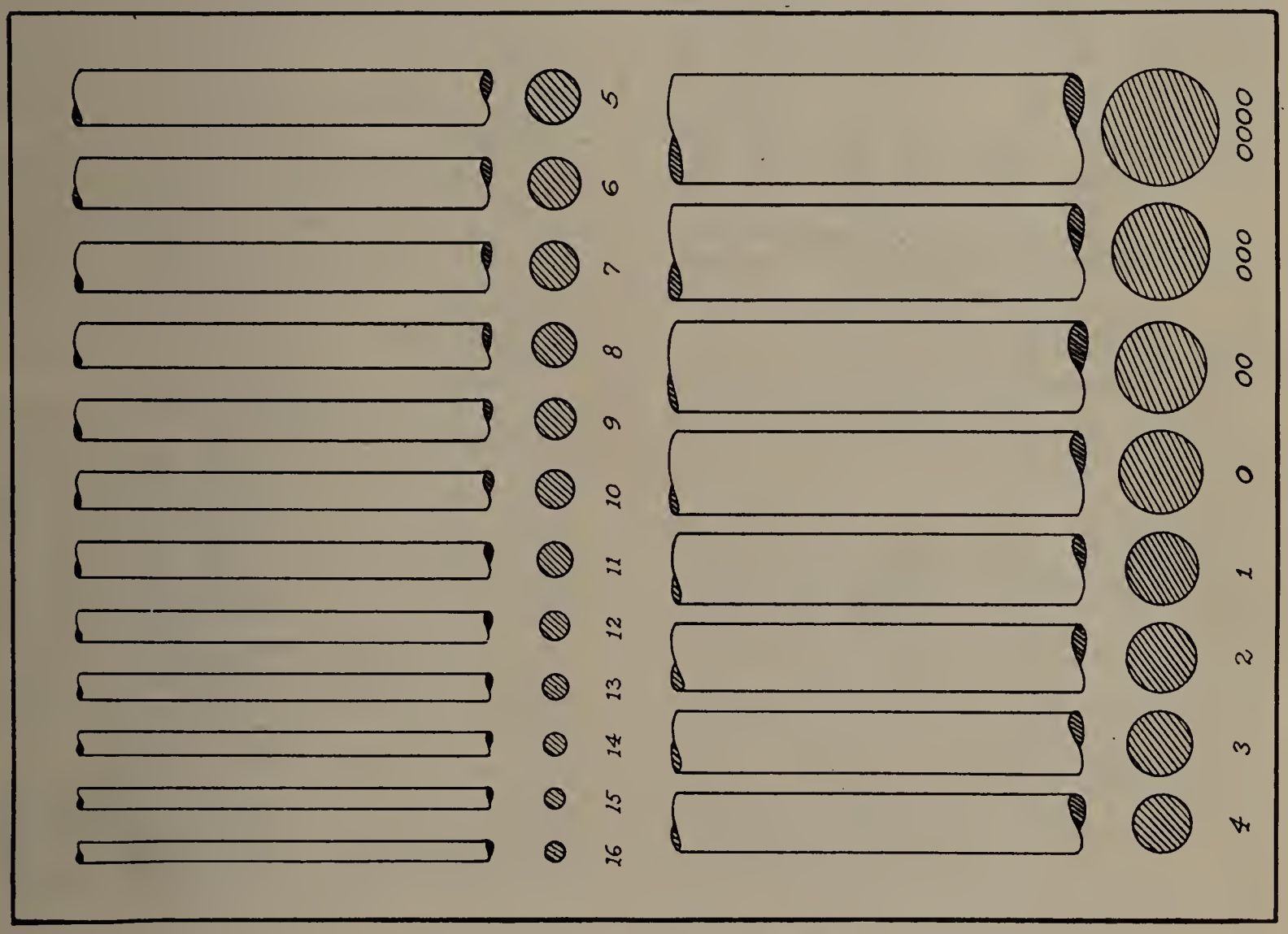


Chart of Welding Rod Sizes

E-No. 1B

Carbon	0.13—0.18 of one per cent
Manganese	0.40—0.60 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent
Silicon	not over 0.06 of one per cent

The difference between E-No. 1A and E-No. 1B electrodes is one of chemical composition incident to manufacture only. In order to assure uniformity of product close limits are demanded. Either E-No. 1A or E-No. 1B may be supplied unless the purchaser, in ordering, specifically excludes either.

Medium Carbon Steel

The data at hand shows that Bare Steel Electrodes having a carbon content of .18 to .85 are of no particular value.

Tests

10. In the hands of an experienced welder electrodes shall demonstrate good weldability in "flat" and "overhead" positions and shall pass through the arc smoothly and evenly without any unusual characteristics.

Packing

11. Electrodes shall be delivered in coils or in straight 14 inch lengths, packed and wrapped as follows:

(a) Bundles of 50 lb. net weight, securely wired and wrapped in heavy weatherproof paper.

(b) Bundles of 50 lb. net weight, securely wrapped in heavy burlap.

(c) Boxes or kegs of 100, 200 or 300 lb. net weight, and wrapped as per paragraph (a).

(d) Boxes or kegs of 100, 200 or 300 lb. net weight, and wrapped as per paragraph (b).

(e) Coils of approximately 50 or 100 lb. net weight, and wrapped as per paragraph (a) or (b).

Marking

12. All bundles, coils, boxes or kegs shall be provided with a metal, linen or strong fibre tag securely wired to or in the case of boxes or kegs, nailed on the outside, bearing the following information:

Make .....
Specif. No. .....
Dia. .....
Nom. Weight .....

Ordering

13. Material ordered under these specifications shall be known as:

"Electrodes, iron and steel, bare," American Welding Society Specifications Number 1, Revised May 1, 1921.

All orders should be specified in pounds. In addition, requisitions shall show the following:

Specif. No.
Size.
Packing.

As a guide in ordering, the following information is of use:

Size, inches	1/16	3/32	1/8	5/32
Lb. per 100 ft	1.04	2.3	4.1	6.5
Ft. per 100 lb	9615	4273	2403	1537
Mils	63	94	125	156
Size, inches	3/16	7/32	1/4	9/32	5/16
Lb. per 100 ft	9.3	12.76	16.7	21.0	26.0
Ft. per 100 lb	1067	700	600	473	383
Mils	188	218	250	281	312

AMERICAN WELDING SOCIETY SPECIFICATIONS FOR GAS WELDING RODS

Iron and Steel

Issued April 1, 1920
Revised May 1, 1921

General

1. The following specifications, prefixed by the letter G, are recommended for the purchase of all iron and steel welding rods for use in gas welding. The uses are specified below.

Scope

2. The welding rods herein specified are recommended as covering the usual railroad, shipyard, and industrial requirements as are allowed by authoritative regulating bodies, such as the American Bureau of Shipping, the Interstate Commerce Commission, etc.

Material

3. Material made by the puddling process is not permitted.

Physical Properties

4. Welding rods shall be made of annealed commercially straight wire of uniform homogenous structure, free from irregularities in surface hardness, segregation, oxides, pipe, seams, etc. Diameter shall not vary more than plus or minus 3 per cent from diameter specified.

Nomenclature

5. The use of the prefix letter G is to indicate that the material is intended for gas welding.

Chemical Composition

6. The chemical composition of the Welding Rods shall be within the following limits:

G-No. 1A

Carbon .....not over 0.06 of one per cent
Manganese .....not over 0.15 of one per cent
Phosphorus .....not over 0.04 of one per cent
Sulphur .....not over 0.04 of one per cent
Silicon .....not over 0.08 of one per cent

Recommended Sizes

7. .....1/16 3/32 1/8 5/32 3/16 1/4 5/16 3/8 inch diameters.

Uses

8. For welding mild steel, structural shapes, plates, bars or low carbon steel forgings and castings.

Surface Finish

9. The surface shall be smooth and free from scale, rust, oil or grease, and may be plain or copper coated.

Tests

10. In the hands of an experienced welder welding rods shall demonstrate good weldability and shall flow smoothly and evenly without any unusual characteristics.

Packing

11. Welding Rods shall be delivered in coils or in straight 36 inch lengths, packed and wrapped as follows:

(a) **Bundles** of 50 lb. net weight, securely wired and wrapped in heavy weatherproof paper.

(b) **Bundles** of 50 lb. net weight, securely wrapped in heavy burlap.

(c) **Boxes** or kegs of 100, 200 or 300 lb. net weight, and wrapped as per paragraph (a).

(d) **Boxes** or kegs of 100, 200 or 300 lb. net weight, and wrapped as per paragraph (b).

(e) **Coils** of approximately 50 or 100 lb. net weight and wrapped as per paragraph (a) or (b).

Marking

12. All bundles, coils, boxes or kegs shall be provided with a metal, linen or strong fibre tag securely wired to or in the case of boxes or kegs nailed on the outside, bearing the following information:

Make .....
Specif. No.....
Dia. .....
Nom. Weight .....

Ordering

13. Material ordered under these specifications shall be known as:

"Gas Welding Rods," American Welding Society Specifications No. 1, revised May 1, 1921.

All orders should be specified in pounds.

In addition, requisitions shall show the following:

Specif. No.
Size.
Packing.

As a guide in ordering, the following information is of use:

Size, inches	1/16	3/32	1/8	5/32
Lb. per 100 ft	1.04	2.3	4.1	6.5
Ft. per 100 lb	9615	4273	2405	1537
Mils	63	94	125	156
Size, inches	3/16	1/4	5/16	3/8
Lb. per 100 ft	9.3	16.7	26	37.5
Ft. per 100 lb	1067	600	383	266
Mils	188	250	312	375

AMERICAN WELDING SOCIETY COATED ELECTRODE FOLIO NO. 1-E*

Chemical Analysis of Coated or Covered Electrodes

Issued May 1, 1921

General

Coated and covered electrodes have a distinct field in arc welding, but the Welding Wire Specification Committee is not prepared to recommend any chemical analyses of material, forms of coating or covering.

The data contained herein is the result of investigation by the committee to date and is offered solely as a guide for the selection of welding material of the nature described.

This folio must not be considered a direct recommendation as investigations have not been completed which would permit the preparation of specifications for this class of material.

Coated and covered electrodes afford a broad field for research and specifications

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**The distinction between specifications and folios is that the specifications are definite recommendations which in accordance with the ruling of the American Bureau of Welding, are to be valid for the period of one year, while the folios contain information which the Welding Wire Specifications Committee offers solely as a guide for the selection of welding material of the nature described. The information in the folios must not be considered as direct recommendations, as investigations have not been completed at this time, which would permit the preparation of specifications for this class of material.*

will be prepared for such electrodes as determined.

Sizes

$\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{9}{32}$ and $\frac{5}{16}$ inch diameters.

Chemical Composition

The following chemical compositions have been successfully used:

Low Carbon Iron or Steel

No. 1

Carbon	not over 0.06 of one per cent
Manganese	not over 0.15 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent
Silicon	not over 0.08 of one per cent

No. 2

Carbon	0.13—0.18 of one per cent
Manganese	0.40—0.60 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent
Silicon	not over 0.06 of one per cent

Uses

For welding mild steel, structural shapes, plates, bars or low carbon steel forgings and castings.

Medium Carbon Steel

Carbon	0,25—0.35 of one per cent
Manganese	0.30—0.60 of one per cent
Phosphorus	(under) 0.04 of one per cent
Sulphur	(under) 0.04 of one per cent
Silicon	(under) 0.12 of one per cent

Uses

Building up worn surfaces that require machine finish, such as Wheel Flanges, Axle Collars, Etc.

High Carbon Steel

No. 1

Carbon	0.60—0.75
Manganese	0.60—0.90
Phosphorus	not over 0.04
Sulphur	not over 0.04

No. 2

Carbon	0.85—1.10
Manganese	0.30—0.60
Phosphorus	not over 0.04
Sulphur	not over 0.04

Uses

For use on high carbon steels and worn surfaces where great resistance to abrasive wear is desired and where machining is not necessary, such as rails, frogs, switch point, bearing surfaces, etc.

Manganese Steel

Carbon	1.10 — 1.35 per cent
Manganese	11.00 —14.00 per cent
Phosphorus	017—.04 of one per cent
Sulphur	007—.04 of one per cent
Silicon	10 —.20 of one per cent

Uses

Manganese Crossing Centers, frogs, switch points, dredge buckets, and other parts where an extremely hard tough surface is required.

Cast Iron

There is not sufficient data on an electrode of cast iron analysis. Therefore, the chemical composition as given for low carbon iron and steel will govern for the present.

Uses

Cast Iron parts studded or general welding.

AMERICAN WELDING SOCIETY FOLIO NO. 1-G

Chemical Analysis of Gas Welding Rods for Welding High Carbon Steels, Non-Ferrous Metals and Mild Steel

(Greater Strength but Lower Ductillty Than G No. 1A)

Issued May 1, 1921

General

The data contained herein is the result of investigation by the committee to date and is offered solely as a guide for the selection of welding material of the nature described.

This folio must not be considered a direct recommendation as investigations have not been completed which would permit the preparation of specifications for this class of material.

This is a very broad field for research and plans are being developed whereby each class of material will be definitely recommended as determined.

Nomenclature

In referring to folio, the analysis prefixed by the letter G indicates the material is intended for gas welding.

Chemical Composition

The chemical composition shall be within the following limits for uses specified:

Medium Carbon Steel

The data at hand shows that welding rods having a carbon content ranging from .06 to .60 are of no particular value.

High Carbon Steel

Carbon	0.60—0.75 of one per cent
Manganese	0.60—0.90 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent

Physical Properties

Rods shall be made of annealed commercially straight wire of uniform homogeneous structure, free from irregularities in surface hardness, segregation, oxides, pipe, seams, etc. Diameter shall not vary more than plus or minus 3 per cent from diameter specified.

Surface Finish

The surface shall be smooth and free from scale, rust, oil or grease, and may be plain or copper coated.

Recommended Sizes

$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$ inch diameters.

Uses

For welding high carbon steel and worn surfaces where great resistance to abrasive wear is desired and where machining is not necessary, such as rails, frogs, switch points, bearing surfaces etc.

Nickel Steel

Nickel	3.25—3.75 per cent
Carbon	0.15—0.25 of one per cent
Manganese	0.50—0.80 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent

Phvsical Properties

Rods shall be made of annealed commercially straight wire of uniform homogeneous structure, free from irregularities in surface hardness, segregation, oxides, pipe seams, etc. Diameter shall not vary more than plus or minus 3 per cent from diameter specified.

Surface Finish

The surface shall be smooth and free from scale, rust, oil or grease, and may be plain or copper coated.

Recommended Sizes

$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$ inch diameters.

Uses

For welding mild steel, producing, however, a weld of greater strength but a lower ductility than secured with G-No. 1A in standard welding rod specifications.

Cast Iron

Carbon	3.00—3.50 per cent
Manganese	0.50—0.75 of one per cent
Phosphorus	0.50—0.70 of one per cent
Silicon	3.00—3.50 per cent
Sulphur	0.10 of one per cent

Physical Properties

Rods shall be commercially straight, of either round, hexagonal or other regular shape.

Surface Finish

The surface shall be cleaned and free from sand, dirt or scale.

Recommended Sizes

$\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$, and in 12 to 18 inch lengths.

Uses

For general welding of cast iron parts.

Tests

Rods when broken shall show a uniform grain of gray cast iron structure.

Yellow Brass

Copper .....60.0—70.0 per cent
Zinc .....40.0 per cent
Iron .....not over 0.06 of one per cent
Other elements....not over 0.10 of one per cent

Material
Cast or drawn.

Physical Properties
Rods shall be straight and of homogenous structure.

Surface Finish
The surface shall be smooth and clean.

Recommended Sizes
$\frac{1}{16}$, $\frac{1}{8}$, $\frac{3}{16}$ and $\frac{1}{4}$ inch diameters.

Uses
For brazing.

Manganese Bronze
No. 1

Copper .....61.0—57.0
Zinc .....37.0—41.0
Manganese ..... .3 to .5 per cent
Aluminum ..... .05 to .15 per cent
Other elements and impurities .....1.35 to 1.65 per cent

Uses
For the general welding of brass sheets, plates, shapes and castings.

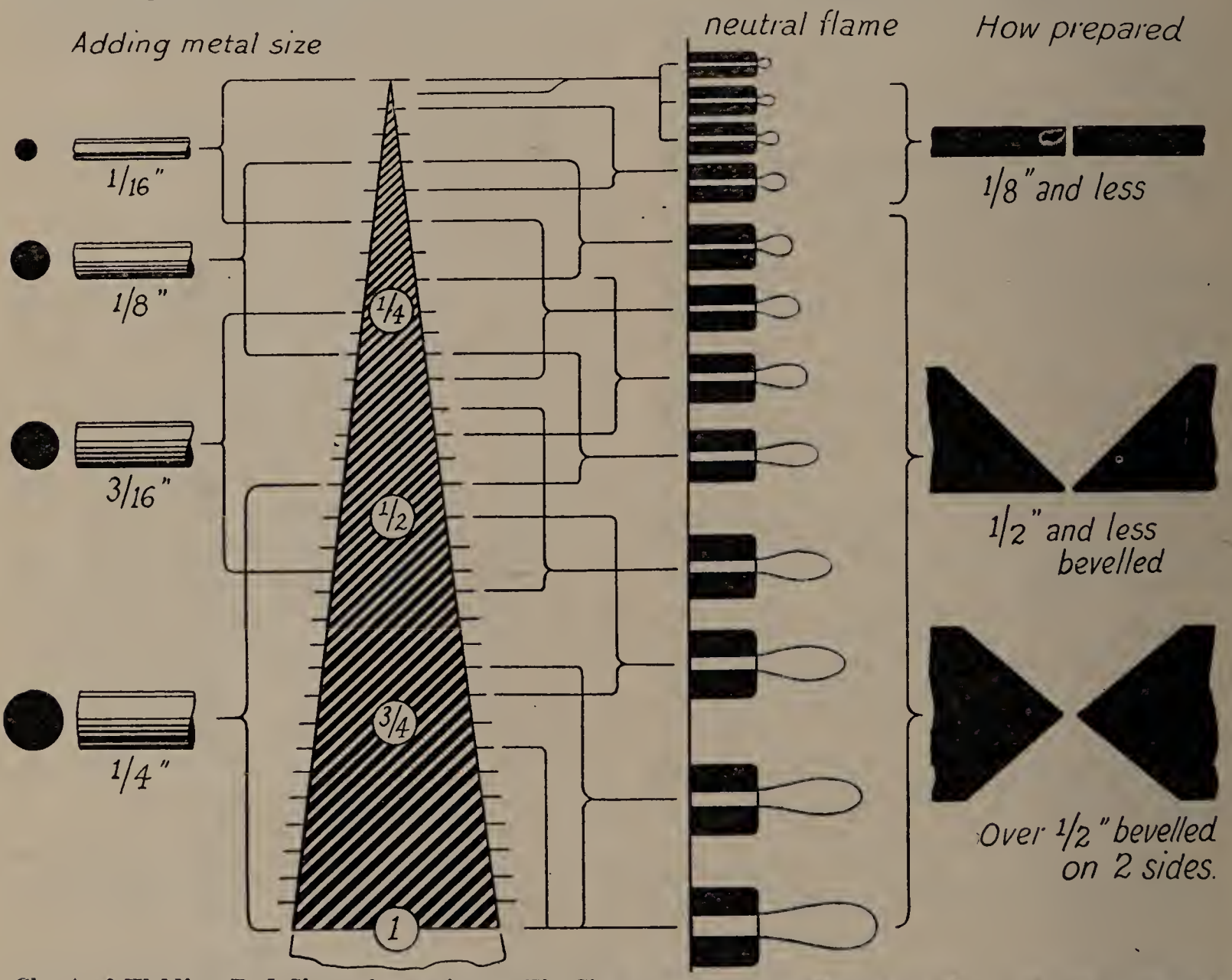


Chart of Welding Rod Sizes, Approximate Tip Sizes, and Method of Beveling for Various Thicknesses of Metal*

No. 2

Copper .....61.0—57.0
Zinc .....37.0—41.0
Iron ..... .5 to 1 per cent
Other elements and impurities .....1 to 1½ per cent
No lead or aluminum allowed.

Uses:
For welding malleable iron bronze and brass where high tensile strength is required.

Material
Cast No. 1 in round sticks.
Cast No. 2 in hexagon sticks (the given dimension, being that across the hexagon.)

Recommended Sizes
$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$ inch diameters.

Aluminum
No. 1

Aluminum .....99.0 per cent

Uses
For the welding of aluminum where great ductility is required.

No. 2

Aluminum .....92.0 per cent
Copper ..... 8.0 per cent

Uses
For the general welding of aluminum.

*Adapted from Instruction Book of Davis-Bournonville Co.

Material
Drawn or cast.
When cast, rods shall be not less than 12 inches long.

Physical Properties
Rods shall be straight and of homogeneous structure.

Surface Finish
The surface shall be smooth and clean.

Recommended Sizes
$\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$ inch diameters.

Tests
In the hands of an experienced welder welding rods shall demonstrate good weldability and shall flow smoothly and evenly without any unusual characteristics.

Packing
Rods shall be delivered in coils or in straight 36 inch length except as otherwise specified and shall be packed and wrapped as follows:
(a) **Bundles** of 50 lb. net weight, securely wired and wrapped in heavy weatherproof paper.
(b) **Bundles** of 50 lb. net weight, securely wrapped in heavy burlap.
(c) **Boxes** or kegs of 100, 200 or 300 lb. net weight, and wrapped as per paragraph (a).
(d) **Boxes** or kegs of 100, 200 or 300 lb. net weight, and wrapped as per paragraph (b).
(e) **Coils** of approximately 50 or 100 lb. net weight, and wrapped as per paragraph (a) or (b).

Marking:
All bundles, coils, boxes or kegs shall be provided with a metal, linen or strong fibre tag securely wired to or in the case of boxes or kegs, nailed on the outside, bearing the following information:
Make .....
Nom. Weight .....
Note:—For the purpose of identifying welding material of different compositions it is suggested that the user designate a color for each metal, this color to be applied to the bundle or to the ends of the wire or rods when the material is placed in storeroom.

"Weldit"
Trade name for welding and cutting torches, supplies, accessories, etc. Made by Weldit Acetylene Co., Detroit, Mich.

"Weldite"
Trade name for welding rods for gas and electric welding. Made by Chicago Steel and Wire Co., 103rd St. and Torrence Ave., Chicago, Ill.

"Weldograph"
Trade name for mechanically operated acetylene welding torch, for sheet metal work. Formerly made by Davis-Bournonville Co., Jersey City, N. J. Now made by Air Reduction Sales Co., 342 Madison Ave., New York. See Table of Contents, Catalog Section.

"Weldox"
Trade name for asbestos paper, gloves, aprons, etc., for welding and welders. Made by F. D. Farnam & Co., 359 N. Wells St., Chicago, Ill.

"Weldrite"
Trade name for A. C. electric arc welding machine. Made by Electric Welding Machine Co., Detroit, Mich.

"Westinghouse"
Trade name for electric arc welding equipment. Made by Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa. See Table of Contents, Catalog Section.

"Wiederwax"
Trade name for a patented oven or furnace for preheating. Made by Geist Mfg. Co., Atlantic City, N. J.

"Willis"
Trade name for welding and cutting torches and acetylene generators. Made by Henderson-Willis Welding & Cutting Co., St. Louis, Mo.

"Willson"
Trade name for goggles, masks, shields, etc., and devices for eye protection for welders. Made by Willson Goggles, Inc., Reading, Pa.

"Wilson"
Trade name for shields and electrode holders for arc welding. Made by Wilson Welder and Metals Co., 132 King St., New York, N. Y. See Table of Contents, Catalog Section.

"Winfield"
Trade name for electric spot and butt welding machine, etc. Made by The Winfield Electric Welding Machine Co., Warren, Ohio.

Wire Cloth
To weld thin sheets of wire cloth, clamp them together by means of steel bars of the proper length. Allow a projection of about $\frac{1}{8}$-inch for welding. The torch flame will fuse the projecting edges together without the use of either rod or flux. Be careful not to overheat or carbonize the metal, for it is usually necessary to open up the sheets after welding, and hammer the joint down smooth and straight. It is not practical to attempt to patch in a new piece where a hole appears in a wire cloth or screen, but the screen can be restored for additional service by filling in the hole completely or welding a piece of thin sheet metal over it.

"Wodack"
Trade name for portable electric drills, grinders, and chippers. Made by Wodack Electric Tool Corporation, 25 S. Jefferson St., Chicago, Ill.

"W. P. Metal"
Trade name for an alloy used for repair work on cast iron, bronze, copper, brass and aluminum. Made by Welded Products Co., 44 Market St., Muskegon, Mich.

—X-Y-Z—

"XL"
Trade name for a flux for thin sheet aluminum. Made by Morey Flux & Chemical Co., Parkesburg, Chester Co., Pa. See Table of Contents, Catalog Section.

"Yankee"
Trade name for acetylene generators. Made by American Generator Co., Kansas City, Mo.

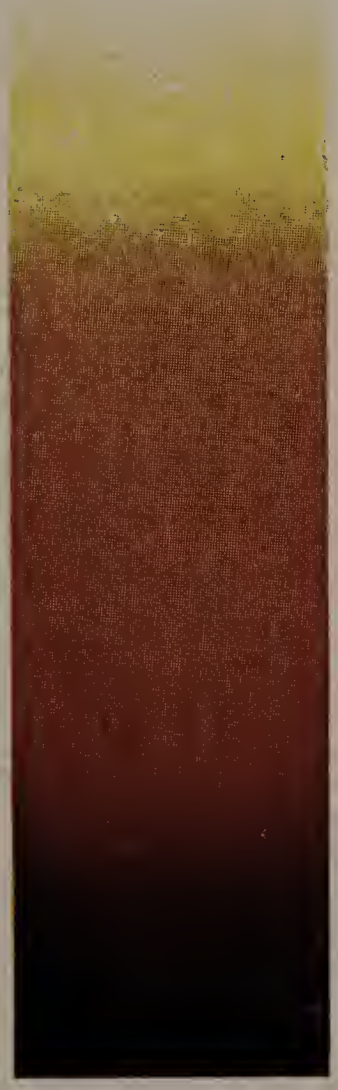
"Zeno"
Trade name for electrode holders for arc welding Made by Gibb Instrument Co., Bay City, Mich. See Table of Contents, Catalog Section.

Zerener Process of Electric Welding
This process employes two carbon rods fastened in a holder so that their ends converge. An arc is drawn between the converging ends and caused to impinge on the work by means of a powerful electromagnet. This is also known as the "electric blowpipe" method of welding. It requires so much skill that it is impractical.

"Zeus"
Trade name for electric arc welding apparatus. Made by Gibb Instrument Co., Bay City, Mich. See Table of Contents, Catalog Section.

The Modern Welding Shop Is Equipped for Both Gas and Electric Welding.

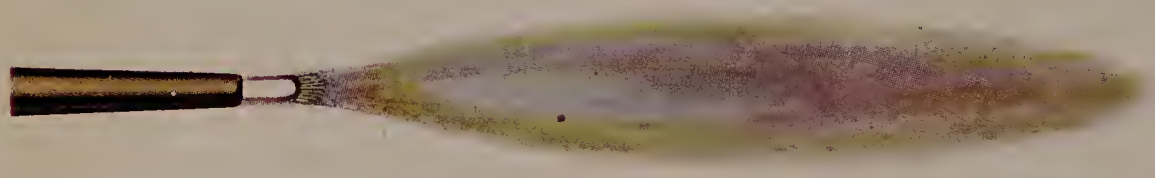
Temperature Color Chart

NAMES	COLOR SCALE	CENT.	FAHR.
11 White		1204°	2200°
10 Light Yellow		1079°	1975°
9 Lemon		996°	1825°
8 Orange		941°	1725°
7 Salmon		899°	1650°
6 Bright Red		843°	1550°
5 Cherry or Full Red		746°	1375°
4 Medium Cherry		677°	1250°
3 Dark Cherry		635°	1175°
2 Blood Red		566°	1050°
1 Faint Red		482°	900°

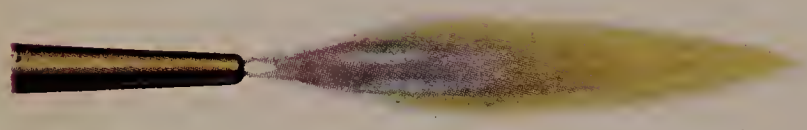
Note: Temperature Color Charts can, of course, give nothing more or less than a graphic suggestion of the relation between the heat colors of metals and temperatures.

The Oxy-Acetylene Flame

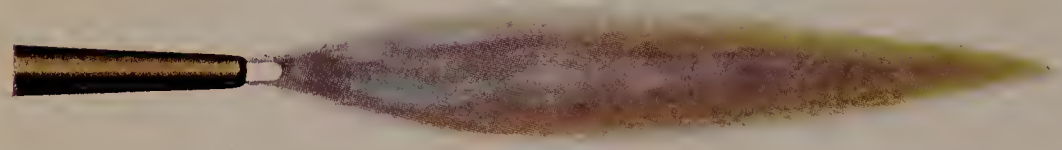
The Acetylene Flame is produced by burning pure acetylene with air. The correct adjustment of acetylene pressure is denoted by the flame jumping away from the tip. The acetylene should be lighted and adjusted before the oxygen needle valve is opened. For complete information regarding acetylene, see under "Acetylene," Encyclopedia Section.



The Carbonizing Flame is produced by burning an excess of acetylene. It can be easily recognized by the feathery edge of the white cone. This flame introduces excess carbon into the weld. See under "Carbonizing Flame," Encyclopedia Section, also the introduction to the chapter on "Oxy-Acetylene Welding."



The Oxidizing Flame is produced by turning on excess oxygen, and can readily be recognized by its shorter envelop of flame and the small pointed white cone. Welding with this flame results in oxidizing or burning metal. For further details, see under "Oxidizing Flame," Encyclopedia Section.



The Neutral Flame is produced by burning the correct mixture of oxygen and acetylene. The clear, well defined white cone indicates that the flame is correct. Welds made with it should be thoroughly fused and free from burned metal or hard spots. See under "Neutral Flame," Encyclopedia Section.

Securing the correct flame adjustment is the first step toward correct welding with the Oxy-Acetylene torch. The neutral flame must not only be established at the start of the welding operation, but it should also be maintained until the work is completed, because the slightest deviation from thorough combustion of gases will result in introducing one of these gases into the molten metal.

ELECTRIC ARC WELDING

Introduction*

THAT the electric arc can be used for depositing ferrous material for repair and manufacturing purposes has been known for over thirty years. In fact the fundamental patent involving the now generally known carbon electrode process was allowed to N. V. Benardos, of Petrograd, in 1887, whereas the patent for the metallic electrode process was allowed to a Mr. Coffin in 1889. As has been the case however with many desirable inventions the industrial world has been slow to make practical application of the disclosed processes. In fact it has only been within the last decade that electric arc welding has been used to any great extent in the repair of damaged or defective ferrous materials. It has been even more recent that the processes have been applied to regular manufacturing production. Probably the chief reasons for the apathy of the industrial world are the haphazard methods of applying the process and lack of proper supervision. inspection and knowledge of the fundamental essentials for producing satisfactory welds.

This state of affairs is being gradually dissipated due to greater publicity of data by a number of large manufacturing companies, The Welding Engineer, The American Welding Society, and similar organizations, which have been and are conducting scientific investigations establishing the most effective materials, apparatus methods and processes for the execution of thoroughly dependable and easily produced arc welds in various types of material. In a considerable portion of arc welding literature however, much emphasis has been laid upon the supposedly essential merits of certain so called "welding systems"—"automatic system of heat control of the arc" and discussions of "constant current systems" versus "constant potential systems." These discussions together with the tendency of most welders to throw an atmosphere of mystery around their welding ability, have resulted in inexcusably ignoring more important data and also have unnecessarily confused unsophisticated persons, who have attempted to get at the facts.

The three chief requisites, especially in the greatest field namely welding of mild steel, are (1) a suitable form of electrical energy and control, (2) electrode material of proper physical, chemical and electrical characteristics, and (3) a trained and experienced welder or operative. It is hardly correct to say that any one of these factors is the most important. However, securing proper electrical equipment and electrode material when accomplished, dismisses the first two factors, whereas obtaining trained and experienced welders or securing suitable men to be trained often resolves into an appreciable problem. For this reason therefore many authorities have estimated the importance of the third factor as 90% of the total problem. It is not within the province of this chapter, however, to discuss the labor problem.

Electric Arc Phenomena

By nature electric arc welding is inherently a low voltage application for electric power. For example an arc drawn between a metal plate and a carbon electrode will under most conditions operate at a potential of 35 to 50 volts, whereas an arc drawn between a metal plate and a metal electrode will operate at a potential of 15 to 35 volts, preferably the former as will be explained later. As practically all commercial electric circuits are of a higher potential it is necessary to employ electrical apparatus which will provide the proper potential. Unfortunately the characteristics of the arc preclude its operation directly by electrical energy derived from a constant potential source. This is due, as is well known, to the peculiar resistance of the arc stream. All ordinary materials in the metal class such as iron, copper, etc., have a constant resistance at a given temperature, therefore if the current thru a given resistance is increased the voltage across the resistance must be increased. The arc stream resistance, however, does not follow this law. In fact, if the current is increased through an arc in air of a given length the resistance of the arc actually decreases therefore the voltage across the arc is decreased. In other words a smaller voltage is required to force a large current through a given arc length than is required for a lesser current. It is obvious, therefore, that if an arc circuit were connected to a constant potential circuit of unlimited capacity the arc current would build up to a tremendously large value. It has been found necessary, therefore, to connect a ballast resistance or reactance or a combination of both in series with an arc which receives power from any source except that of a strictly constant current character.

Selection of Electrodes

The use of metallic electrodes for arc welding has proven more satisfactory than use of carbon or graphite electrodes which necessitate feeding the new metal into the arc by means of a rod or wire which is melted. The chief reason for this is that when the metallic electrode process is used, the end of the electrode is melted, the molten metal being carried through the arc and deposited at the other end of the arc on the material being welded at which point the material is in a molten state produced by the heat of the arc, thereby producing a perfect union or fusion with the new deposited metal. In the hands of an experienced and careful welder, equally good results can be obtained with the carbon electrode process. However, if the operator is inexperienced or careless, he is liable to fail to produce good fusion continuously due to feeding in the new metal too rapidly. As a result, the new metal will flow over portions of the work which have not been brought to the molten or fusing state. Probably the chief field of usefulness for the carbon electrode is that of cutting or for rapid repair welding where strength of weld is not as important as the speed of doing the work.

For metallic electrode welding of mild steel plates, an electrode containing about 17[2] points (0.17 per cent) carbon and 50 points (.5 per cent) manganese, has been found most satisfactory. The percentage of phosphorus, sulphur and silicon should be as small as possible, not to exceed 0.03 to 0.035 per cent for the first two, and not over 0.01 per cent to 0.015 per cent for the last. This same

Written for The Welding Encyclopedia by A. M. Candy.

[2]*Many authorities recommend a much lower carbon content. The welder should always consult a reputable welding rod manufacturer regarding the selection of electrodes for various purposes. See also "American Welding Society Specifications" under "Welding Rods and Wire" in Dictionary Section.*

material is also satisfactory for welding steel castings, and cast iron castings, including the malleable variety. When subsequent machining is to be done on cast iron castings, better results can be obtained by using a copper-aluminum alloy electrode and a suitable flux. Some operatives have found that excellent results can be obtained by depositing a comparatively thin layer of the alloy over all the prepared surfaces, after which the main body of the weld is made with the steel electrode mentioned above. It is comparatively difficult to use the alloy electrode, however, due to its low melting temperature and tendency to drop off the end of the electrode in large globules. There-

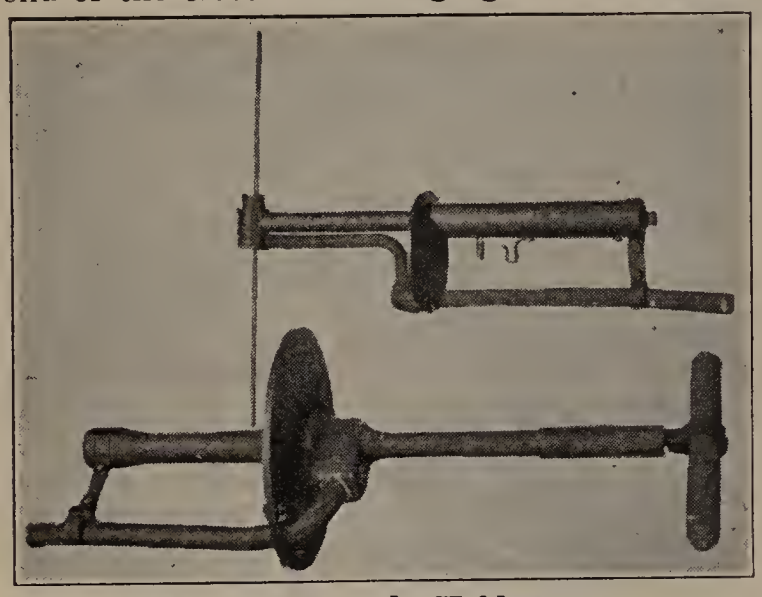


Fig. 1. Electrode Holders.

fore material greater than ¼ inch in thickness must be preheated. The analysis of the electrode shows the presence of 88.48 per cent copper, 3.32 per cent iron, 8.14 per cent aluminum, a trace of zinc and no tin. The flux supplied with the electrode consists 68.4 per cent Na_2CO_3, 22.6 per cent NH_4CL. 0.5 per cent Na_2SO_4. Owing to the characteristics of the electrode and flux a considerable amount of slag is formed which is rather difficult to remove from the body of the weld during the operation. It is safe to predict, therefore, that this material will only yield satisfactory results in the hands of expert welders. Good results have been produced also by using nickel-manganese rods (92 per cent nickel, 8 per cent manganese) for filler material.

What Current Shall Be Used?

The diameter of the metallic electrode required is determined by the current to be used, which is dependent upon the thickness of the plate to be welded when the thickness is ¾ inch or less. Average values for welding of mild steel plates are indicated by Fig. 2. For example, select a ⅜ inch plate and follow horizontal line until plate thickness curve zone is intersected. The vertical line through this intersection represents about 110 amperes. Following the vertical line to the intersection with the electrode diameter curve, locates a horizontal line representing approximately a $\frac{5}{32}$ inch diameter electrode as required. Similarly, a ½ inch plate requires about 125 amperes and a $\frac{5}{32}$ inch electrode. These values of current for plate thickness are only approximate, however, as the type of joint and temperature of the plate will materially influence the volume of current which can be used, therefore, a zone curve is shown instead of a line curve. For example, when making a lap weld between two overlapping ½ inch steel plates at ordinary temperature of about 65 degrees F., it has been found that the best results were obtained by using a current of about 225 amperes and a $\frac{3}{16}$ inch diameter electrode. The explanation for the high current permissible is the tremendous heat storage and dissipation capacity of the lapped plates.

Short Arc Is Essential

The maintenance of the proper arc length for the metallic electrode process is very important. To state the length briefly, it is to say that the arc should be just as short as it is possible for a good welder to maintain it. Under normal good conditions, the arc length should be such that the voltage drop never exceeds 25 volts and for best results the potential should be between 18 to 22 volts. For a 175 ampere arc, the actual gap will be about ⅛ inch. If the arc is maintained long the natural air drafts will cause it to move around an extended surface of the work, preventing good fusion and causing a thin deposit of the new metal. If, however, the arc is maintained short much better fusion is obtained the metal will "bite

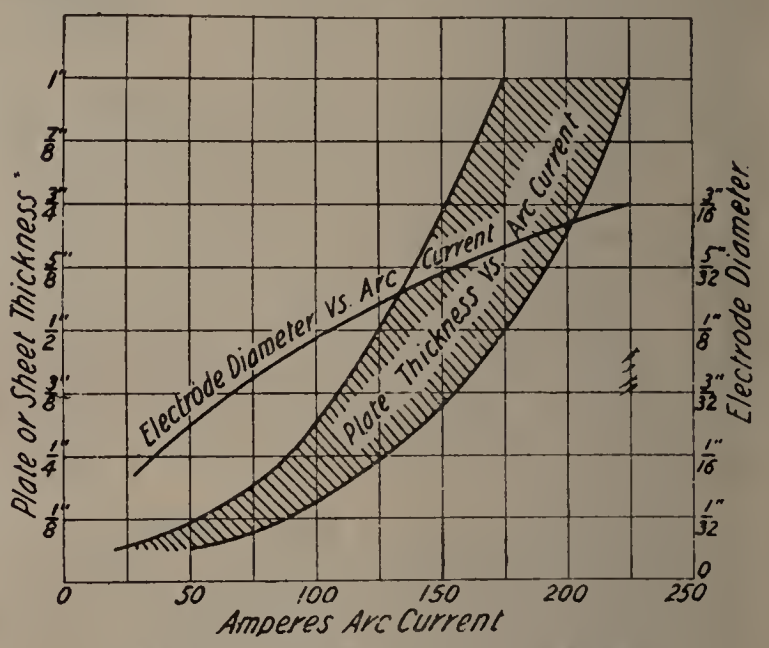


Fig. 2. Average Current Values.

into" the work, and the new metal will be confined to a smaller area, furthermore, it is more completely enveloped by the gases surrounding the arc which are inert and thereby protect the new metal from atmospheric oxygen thus reducing burning and porosity of the metal.

Electrically operated switching devices have been developed, which prevent the welder from drawing a long arc by automatically "killing" the arc when it has reached a certain length. These devices perform their function satisfactorily, but are subject to several criticisms. First, they entail a needless expense both first cost and maintenance, because a man who will ultimately make a good welder can be made to see the desirability of maintaining a short arc and will, therefore, do so automatically within reasonable limits. Second, not even the most skilled welder, can maintain a continuous arc never exceeding 25 volts. In fact, momentary variations of arc length due to involuntary reflexes of the operator's arm muscles, may occur frequently, but will not be of sufficient duration to result in appreciable damage to the weld. If, therefore, a switch is provided to automatically kill the arc when the voltage drop reaches 25 to 30 volts, the operator will be troubled by having to restrike his arc quite frequently, which will decrease his production and increase the number of arc craters which are always oxidized, producing weak areas in the finished weld.

Filling Sequence

When making a long seam weld between two plates, the operator is always confronted by the problems of expansion and contraction, causing warpage of the plates and the production of internal strains, both in the plates and the deposited material. To most satisfactorily minimize these difficulties, some operators have found by practical experience, that the best method to pursue is as follows: After preparing the edges of the plate, light tack welds are made about eight inches apart along the entire seam. The operator then makes a complete weld between the first two tacks and then skips

three spaces and welds between the fifth and sixth tacks and so on until end of seam is reached. This skipping process is again repeated by starting between second and third tacks and so on until the complete seam is welded. The object is to permit the heat in a restricted area to be dissipated and radiated before additional welding is performed near that area. Therefore, the weld is made on reasonably cool sections of the plates, which keeps the expansion at a minimum. This is one example of numerous shop kinks, which are evolved by alert aggressive welders, and is known as the "rigid method" of welding plates. This method is used extensively in the welding of locomotive fire boxes. For sheet metal tank construction some authorities recommend the "rigid method," whereas others recommend making a shrinkage allowance by placing the edges, to be welded at an angle with each other instead of parallel. The weld is commenced at the apex of the angle and is continued by completely filling the seam at each point before progressing across the plate. If the plates are properly spaced at the end of the seam farthest from the beginning of the weld the contraction of the filler metal will just close the seam when welding is finished. Still other authorities recommend making the seam weld by a series of small strings of metal, the first one at bottom of scarf angle continuing across the plates, the second one along the surface of one plate, the third along the surface of the second plate thus alternating until the entire seam groove is filled. The theory underlying this method is that each subsequent string of metal will transfer heat to the previous deposits, thereby annealing them and also since the sectional area of metal at a high temperature at any time is exceedingly small the internal cooling strains will be reduced.

Heat Treatment of Welds

The question of subsequent heat treatment of welded materials is a very broad one and represents a field offering opportunities for a vast amount of research and investigation by metallurgists. In general, however, ordinary commercial welding of mild steel plates and steel castings, if properly executed, will not require subsequent heat treatment. In fact heat treatment only yields the most markedly beneficial results when applied to high carbon and alloy steels. In the case of cast iron the weld must be given an annealing treatment if the parts are to be machined after welding. Since the metal deposited in welding is essentially commercially pure iron, it is hardly conceivable that any form of heat treatment could give it the same chemical and physical characteristics as steels which have been subjected to mechanical rolling.

The opinion is apparently quite generally held that the cooling strains set up in welds will materially reduce their strength. To determine the value of such contentions the following tests were made.

Steel bars ¾ inch thick, 1 inch wide, 6 inches long were scarfed to 45 degrees, separated $\frac{1}{16}$ inch and welded with Roebling electrode $\frac{5}{32}$ inch in diameter with an arc current of 180 amps. Bars No. 1, 2, 3, and 5 were clamped rigidly to a cast iron plate to prevent distortion during welding and cooling thereby reproducing the strain conditions obtained in the rigid method of welding plates. The test bars are hot rolled stock having a tensile strength of 49,000 pounds per square inch the chemical composition being 0.19 per cent carbon, 0.45 per cent manganese, 0.008 per cent phosphorus, 0.017 per cent sulphur and 0.047 per cent silicon.

Bar No. 1 welded and air cooled in clamp tested 46600 pounds per square inch.

Bar No. 2 welded and air cooled in clamp. Then removed from clamp heated in furnace to 760 degrees C., allowed to cool slowly for 16 hours to room temperature. No perceptible change in alignment was observed to result from the annealing. Bar tested 47500 pounds per sq. in.

Bar No. 3 welded and air cooled in clamp. With clamp still in place the piece was placed in furnace, heated to 760 degrees C., then allowed to cool for 16 hours to room temperature. Bar tested 42400 pounds per square inch.

Bar No. 4 welded free from clamp (nor rigid method) and air cooled. Center of bar was ⅜ inch out of alignment with the ends due to shrinkage of filler. Total length of welded bar 12 inches.

Bar No. 5 welded in clamp and while filler was still at cherry red heat, bar was plunged into water. After cooling bar was removed from clamp and heated in annealing oven to 760 degrees C., and then cooled slowly for 16 hours to room temperature. No appreciable change in alignment of bar as a result of annealing was noticeable. Bar tested 44000 pounds per square inch. The test on bar No. 4 shows clearly, by the distortion obtained, that some residual strain must remain in a rigidly welded unannealed bar, however, tests on bars No. 1, 2, 3 and 5 indicate that the stress is apparently negligible.

The Arc Welder and Its Uses.*

Electrical Circuit

THE path over which an electric current flows is called an electrical circuit. A given point in an electrical circuit is positive with respect to another point when the direction of flow of current is from the first point to the second. The intensity or pressure of the electric current is expressed in terms of volts. The rate of flow of current in the circuit is expressed in terms of amperes. In a direct current circuit, or, as it is sometimes called a continuous current circuit, the product of the volts and the amperes in the circuit represent the amount of electrical energy flowing. The product of the volts and the amperes in the circuit, together with the time of flow represent the watt hours of energy expended in the circuit. Electrical energy is usually expressed in kilowatt hours. Each kilowatt is a unit of one thousand watts.

As an example of this sort of calculation the voltage across a portion of an electrical circuit may be taken as 50 volts and the current flowing in the circuit as 600 amperes. The amount of power being consumed in the circuit is 30 kilowatts, or 30,000 watts. If the circuit is maintained for half an hour 15 K. W. hours of electric energy will be expended.

The efficiency of an electrical machine is ordinarily taken as the ratio of the output of the machine to the input. If an electric generator has an output of 30 K. W., but requires an input of 50 K. W., the efficiency would be taken as the ratio of 30/50 or 60 per cent.

The Electric Arc

An electric arc is an incandescent stream of metallic vapors which carry an electric

**Written for The Welding Encyclopedia by R. E. Kinkead, with additions by the Editors.*

current. An electric arc is formed when two conductors of an electric circuit are brought together forming an electrical contact, then separated and there is sufficient voltage available to maintain the current of electricity through the intervening gaseous medium. Arc phenomena vary widely as the voltage between the conductors is increased. No attempt is made in this discussion to deal with high tension or high voltage arcs.

In a continuous current arc the conductor from which the current flows is called the positive electrode or anode. The conductor to which the current flows is called the negative electrode or cathode. The heated gases are sometimes called the arc flame.

The arc being a part of an electrical circuit is subject to the same fundamental law. The product of the voltage across the arc and the current in amperes flowing in the circuit represent the amount of energy present in the arc. By introducing the time element the amount of power consumed by an electric arc can also be calculated. Thus, a 40 volt, 300-ampere electric arc used for one hour will consume 12 K. W. hours of electrical power.

The relationship between electric energy and heat is:

One K. W. hour equals 3413 B. T. U.

From this it will be noted that an electric arc may be considered as a transformer of electrical energy to heat.

The distribution of heat in an electric arc depends upon the density of current in the electrode. At the densities used in welding practice from ⅔ to ¾ of the total amount of electrical power converted into heat is expended at the positive electrode at the point at which the electric current passes from the solid medium of the electrode to gaseous medium of the flame. The balance of the heat is produced in the arc flame and on the negative electrode.

The area of the positive electrode from which the electrical current actually flows depends upon the amount of current flowing in the circuit and the atmospheric pressure surrounding the arc. At atmospheric pressure the arc is confined to a relatively small area. Since the total amount of electric power transformed into heat is relatively large the heat is of great intensity or temperature. The atmospheric pressure being approximately constant the temperature of an electric arc is for all practical purposes constant. While no attempt has been made to reduce the temperature of the arc by reducing the atmospheric pressure, research in this direction is being undertaken. Temperature of the arc and the amount of heat transformed from electrical energy by the arc should not be confused. The amount of heat in an electric arc may be practically anything, but the temperature, whether the amount be large or small, is the same for any given positive electrode.

Utility of the Electric Arc for Welding Purposes

The high temperature of the electric arc makes it valuable for welding purposes because any metal which is to be welded can be melted by the arc. Another important feature of the arc for welding purposes is that the large part of the heat is produced in the positive electrode where it will be most effective for melting the metal. Where metal is melted for welding purposes by a combustion flame the heat is always produced external to the metal and merely blown on to the point where molten metal is desired. Thus, in carbon electrode welding of steel where an arc is drawn between the carbon electrode and a piece of steel a large part of the heat is produced in the steel and such metal as is to be added is fed into the arc in the form of a filling rod. In metal electrode welding on the other hand, the metal to be added is made the negative electrode. The negative electrode is in the form of a melt bar, rod or pencil and is melted with such heat as is ordinarily produced on the negative electrode, together with the heat coming by radiation from the positive electrode.

The high thermal efficiency of the electric arc for welding purposes due to the fact that the heat is produced largely in the metal of the positive electrode is from 3 to 10 times the thermal efficiency of a combustion flame used for the same purpose, owing to the fact that in the combustion flame a large part of the heat is wasted by conduction and deflection of the flame from the point at which molten metal is required.

Electrodes for Electric Arc Welding

Where the carbon electrode is used for welding purposes it has been found that the graphite electrode as distinguished from the hard carbon electrode, yields longer life than any other.

The current density used in an electrode depends largely upon the character of work done. It has been found that high current density in a carbon electrode adds to the stability of the arc and makes it more easy for the operator to control. On the other hand, a low density in the electrode means longer life and less heating of the electrode holder.

The table given below gives probably the average of the current values used on the various sizes of carbon electrodes for cutting and welding purposes.

3/16	inch diam.	75-amperes.
¼	inch diam.	100-amperes.
⅜	inch diam.	200-amperes.
½	inch diam.	300-amperes.
¾	inch diam.	400-amperes.
1	inch diam.	600-amperes.

variety of metal electrodes is used. Practically any standard brand of dead soft iron or low carbon steel welding wire (with a low percentage of impurity can be used provided it is given a coating which has a suitable alkaline base. There are a number of different trade names which apply to dead soft steel wires, which can be used satisfactorily in the metal electrode process, without any coating. Whether the wire is coated or not, the results obtained are very nearly the same, but for careful work there are many operators who show a decided perference for the coated wire.

As the percentage of elements such as carbon, manganese, nickel, etc., are increased in the welding wire the tendency is to increase the tensile strength of the metal in the weld. However, in bare wire welding there is certain to be a difference in the material added depending upon what the original analysis of the electrode might have been so far as ductility is concerned.

The use of electrodes having high percentages of the above mentioned impurities is extremely difficult where the electrode is used bare. The difficulty in using electrodes of this nature arises from the fact that the metal is extremely "wild" in the arc while it is being melted. The addition of a lime, or other covering of similar nature, to such electrodes contributes materially to the success of the operation.

The use of covered electrodes permits the use of the alloy steels for metal electrode welding. Under certain conditions the use of the covering on the electrode will give an appreciable degree of ductility to the metal deposited by the electric arc welding process. The presumption is that this is due to the fact that the oxygen and nitrogen of the atmosphere is to a certain extent excluded from the hot metal during the welding process.

Covered electrodes are of two general classes. The first class being the electrode

which has a heavy covering of scientifically prepared slag which contains a deoxidizer and which most completely protects the molten metal from the action of the gases in the atmosphere. The second class of covered electrodes is the type which has a very thin covering on the wire. The attempt is made with the thin coverings to obtain the same results as far as protection from the atmosphere is concerned without the disadvantage of manipulating the heavy coating of slag during the welding operation.

The use of copper, nickel and bronze electrodes for special purposes has been carried out successfully with and without coatings.

The use of 12 per cent manganese steel as an electrode has proven successful either as a bare rod or using one of the several types of coverings. This electrode is always made positive.

The early attempts of welding with alternating current were most unsatisfactory for the reason that the sine wave current of the ordinary power line or power transformer would not lend itself to a stable arc. The gradual building up of current first in one direction, its decreasing and building up in the opposite direction with the subsequent passing through the zero value did not permit of a stable arc.

It was soon realized that special welding transformers had to be designed capable of producing a stable welding current. This was accomplished in two ways; by superinposing secondary windings, and by magnetic leakage as in the design of the constant current transformer producing a phase displacement and a lagging current.

This distortion of the sine wave resulted in prolonged maximum of both positive and negative current values with subsequent rapid changes through the zero value. This produced satisfactory welding current. The apparatus necessary, namely, the transformer, is a simple apparatus, requiring little upkeep expense. Its size makes it readily portable and it is economical in the use of current.

ELECTRIC ARC WELDING MACHINES

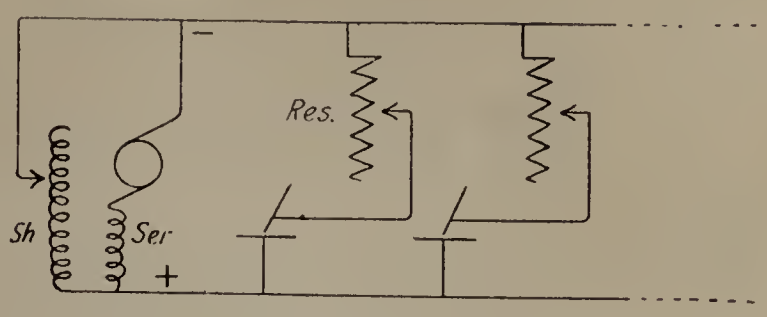
Electric arc welding may be done with any electrical current, having a reasonable degree of stability, and sufficient amount of heat to accomplish fusion. Repeated tests have shown that welding results are dependent on the above factors, rather than upon the power economy or particular characteristics of arc obtained by the use of a specially designed machine. The design of the welding machine affects the cost of doing welding. The necessity for a special machine rests entirely upon economic factors and the differences between the various types used are differences of power cost of operation and differences of speed of operation due to relative stability of the arc.

The direct current arc welding machines illustrated and described here are all of the motor generator type. The motor is a standard machine adapted to the available power supply. The generator is designed particularly for arc welding service to give power economy, and a satisfactory characteristic of the arc. The equipment described is of representative types. Other makes of apparatus are offered for sale in the U. S., England, France and Germany. The alternating current machines described are likewise representative types.

Simplified wiring diagrams are used throughout.

Westinghouse Constant Potential

This type of generator is a flat compound 60 volt generator. It is used as a multiple operator unit usually, although for heavy carbon arc welding it is also used as a single operator set. Inductive ballast may be introduced into each metal electrode circuit to stabilize each arc. The input to the motor is approximately 17 K. W. when the output to the arc is 200 amperes, at 20 volts, across the arc.



Westinghouse Constant Potential

This type of apparatus is used where a large number of operators are concentrated in a relatively small area owing to the fact that advantage may be taken of the fact that all operators will not be welding at the same time. Where 20 operators are working the equipment may only be large enough to carry 12 operators continuously.

The higher power cost of operation of this type of equipment may be offset under certain conditions by the low initial cost due to this "operation factor."

This same type of machine is manufactured by the General Electric Co.

Wilson Constant Current Machine

The Wilson Single-Arc Unit is of the constant current, self-exciting, variable voltage type.

The regulation is obtained by automatically varying the strength of the shunt field. The regulator consists of very few parts. A small reactance or stabilizer is used so that an inexperienced operator will not break his arc.

The control apparatus is equipped with a ballast resistance and it can be adjusted to compensate for long or high resistance welding leads.

There are only two adjustments necessary to regulate the machine over a very wide range. First: Spring pressure on carbon pile that is in series with shunt field. Second: Shunt Field Rheostat that the operator sets for any voltage between 25 and 50 volts, and maintains the current constant for any given setting within 5 per cent.

The power economy of this apparatus is good, due to the small amount of ballast resistance used.

Wilson Constant Potential Multiple-Arc Units

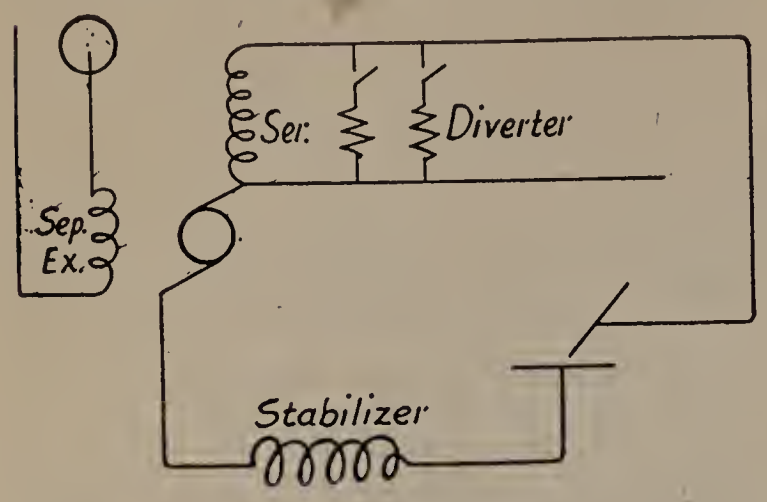
Wilson constant potential apparatus generates 37 5 volts to 42 volts. The generator is flat compound; the resistance ballast is in the form of a carbon pile in series with the arc.

Lincoln Variable Voltage

This type of equipment was the first successful type eliminating the resistance ballast from the arc circuit entirely. The generator field is separately excited, series field "bucking." The open circuit voltage may be anything between 40 and 100. The reduction in voltage to that required by the arc is brought about by the "bucking" series field and armature reaction. Adjustment of amount of current in arc circuit is made by variation of separately excited field and by diverting current from the "bucking" series field.

The over all efficiency of the equipment is about 50 per cent on metal electrode work.

The arc has the characteristic that it may be drawn to lengths up to 5/8 inch suddenly and held for a short interval without breaking. This character is given the arc by the

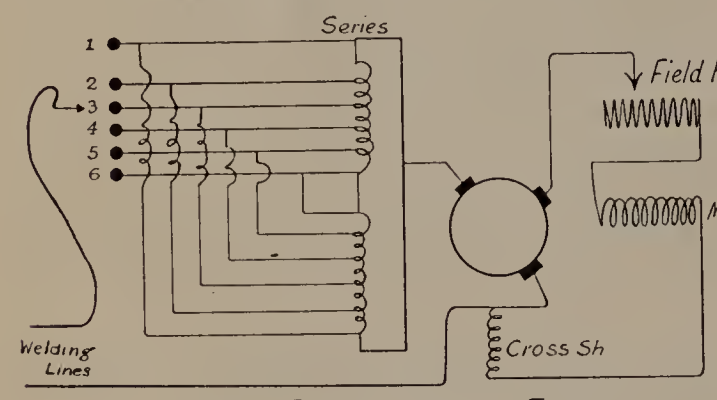


Lincoln Variable Voltage

use of a very heavy inductive ballast or stabilizer and a complete laminated steel magnetic circuit.

General Electric Constant Energy

This type of apparatus takes its name from the fact that it may be adjusted so that the product of the volts across the arc and the amperes in the arc circuit is ap-



General Electric Constant Energy

proximately constant over the operating range of arc voltage.

The open circuit voltage is 60 volts. Reduction in voltage to that required by the arc is obtained from the effect of the armature reaction on the cross flux. The machine is 4 pole with like poles adjacent. The main flux comes from the pair of poles which is saturated. The cross flux poles are operated below saturation so that the armature reaction under load reduces the total flux by reducing the cross flux. The main flux remains constant. Excitation is obtained from the portion of the armature subjected at all times to constant flux.

A "bucking" series field with taps is provided on the cross field poles to assist the armature reaction in order to obtain lower values of current.

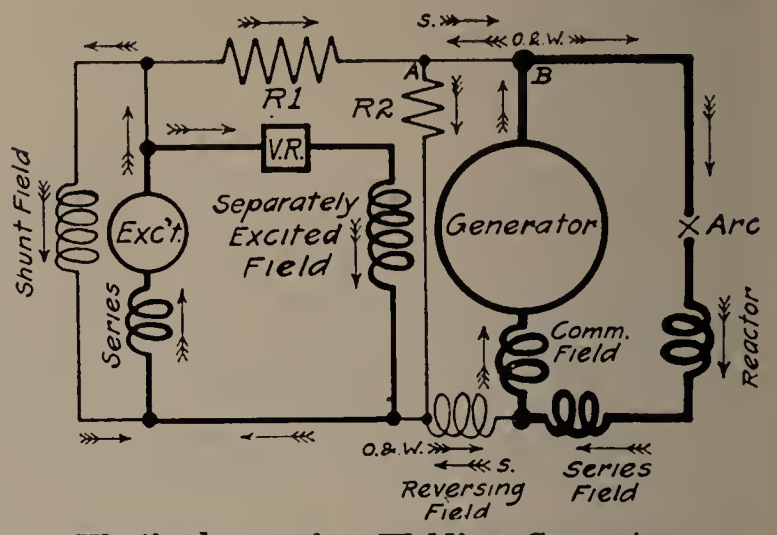
The over all efficiency of the machine is approximately 50 per cent on metal electrode work. This equipment delivers a short arc.

Westinghouse Single Operator

Westinghouse variable voltage equipment eliminates entirely the resistance ballast from the arc circuit. The open circuit voltage may be anything between 30 and 60 volts. Reduction of open circuit voltage to arc voltage is accomplished by a bucking series field and a reversing field. The separately excited field remains constant. As the voltage of the machine falls when the arc is struck due to the bucking series field, the self excited cumulative shunt field changes to a separately excited differential field.

A rheostat in the separately excited field provides the only means of adjustment of arc current. The overall efficiency of the machine is about 50 per cent.

The arc is of the type that is stable, and

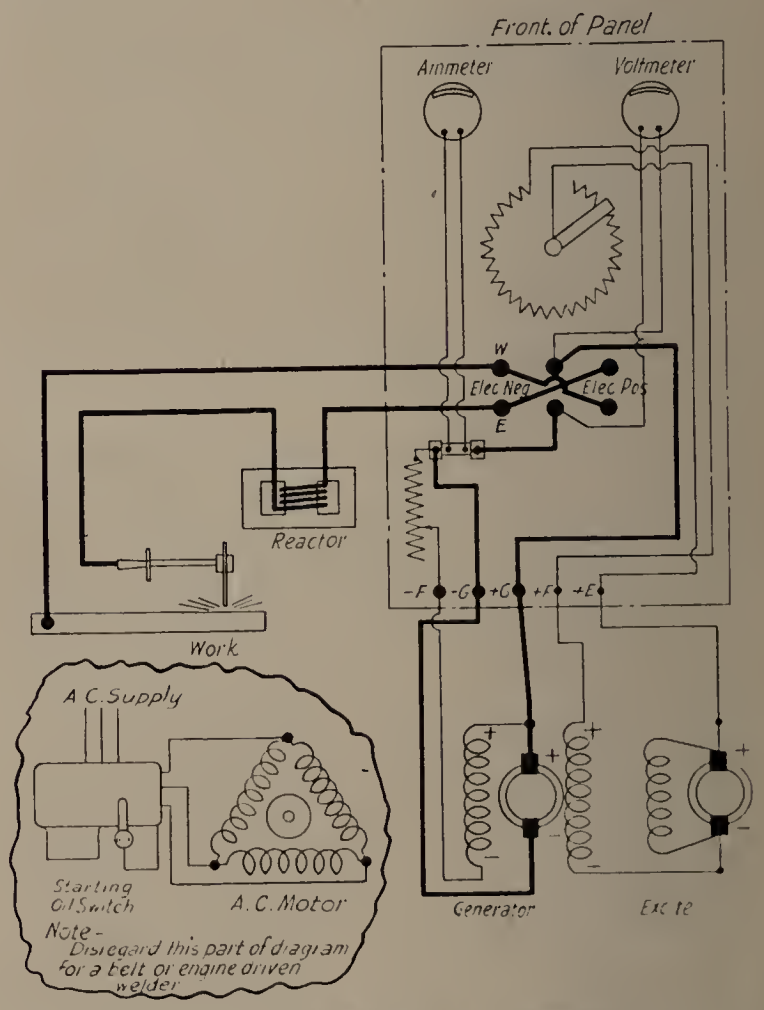


Westinghouse Arc Welding Generator.

will not go out upon suddenly lengthening within the operating range of the equipment.

U. S. L. Arc Welding Generator

The generator is a four pole, self separately excited machine. Each pole is provided with two field windings. One set of field coils is supplied from the brushes of the welding generator, while the other set receives current from a small exciter generator.



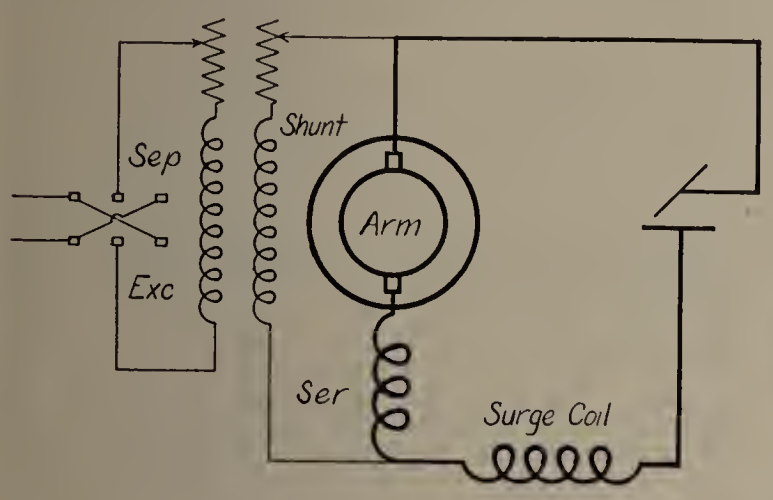
U. S. L. Arc Welding Generator.

The effective flux is produced by the combined action of the self excited and separately excited field Upon applying the load. the armature produces a strong cross flux in accordance with the current output. the strength of the self excited field falls off. since the voltage effective on the brushes is reduced, while the strength of the separately excited field remains unaltered. The generator will supply constant energy at the arc within very close limits over the range of 50 to 225 amps. Current adjustments are obtained by raising or lowering the open circuit voltage by means of the rheostat inserted in the separately excited field circuit. It permits the current adjustments in steps of about 5 to 6 amps. The exciter is a two-pole, shunt wound, 110 volts direct current generator. It is electrically an entirely separate unit. All welders connected to AC motors, to gas engines or belt driven, are

equipped with these exciter generators, while all DC motor driven welders receive their separate excitation directly from the line and hence are not equipped with exciters.

Siemund Wenzel Welding Generator

The Siemund Wenzel arc-welding generator uses a bucking series field to provide the falling voltage previously obtained by means of ballast resistance in the welding circuit. The open-circuit voltage for starting the arc is provided by two field windings; one is excited from a separate source and one from the terminals of the machine.



Siemund Wenzel Welding Generator

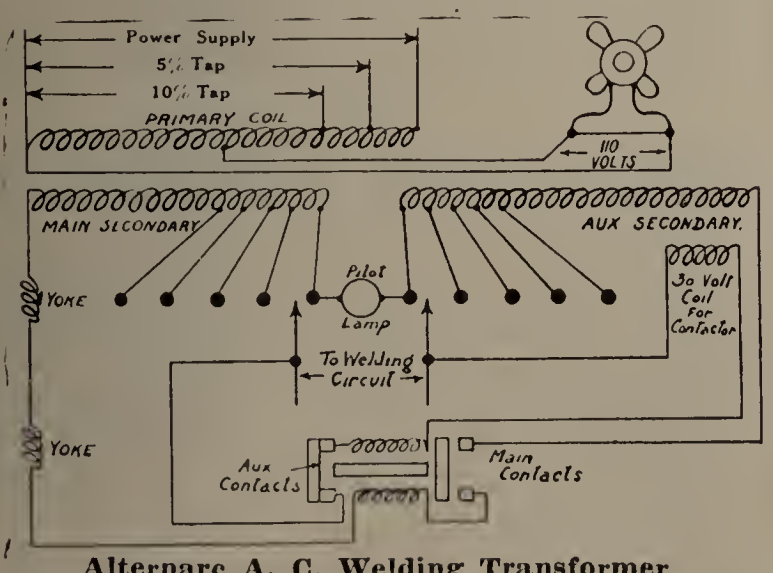
Under normal welding operation, or at short circuit, the effect of the latter, or shunt, field is small, reducing the bucking effect required of the series field. The voltage decreases faster than the current increases, so that the short circuit current, for a given open circuit voltage and series field, is much less than it would be with a resistance circuit adjusted for the same welding conditions. This makes it easy to start the arc.

The shunt and separately excited field windings are so proportioned as to give a firm hot arc which can be immediately restruck if accidentally opened. The characistics of this generator place it in the short arc class.

Adjustment of welding current is obtained by varying the strength of the separately excited field current. The efficiency from generator shaft to arc is approximately 65 per cent.

The Alternarc A. C. Arc Welding Transformer

The main secondary supplies the foundation E. M. F. of the arc. The auxiliary secondary keeps the arc in action by adding its voltage to the foundation voltage, each time the current tends to go to zero, and also

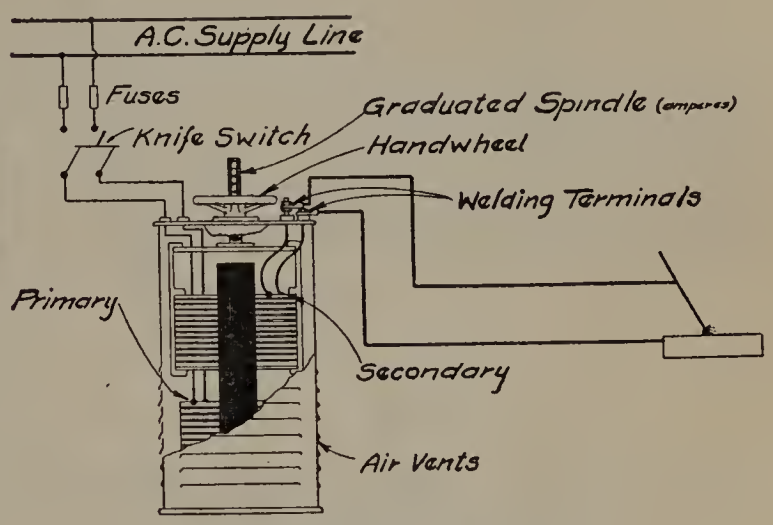


Alternarc A. C. Welding Transformer

subtracts its voltage from the main voltage when the arc tends to short circuit. This action is obtained by the auxiliary secondary obtaining flux from the primary on open circuit, decreasing in amount down to the welding values. On short circuit it has a flux of its own which over-balances the primary thus detracting from the main secondary. The yoke turns act on open circuit with the main and on short cumulative changes. The machine is made to give a constant rate of heat, as the main secondary is a constant voltage transformer and the auxiliary secondary is a constant current transformer, while the machine is a combination of the two, i. e., constant product of currents and volts, or constant rate of heat.

Gibb Alternating Current System:

The Zeus AC Arc Welder is a re-design of the constant-current transformer which has been used in arc lighting. It consists of a transformer with a floating secondary

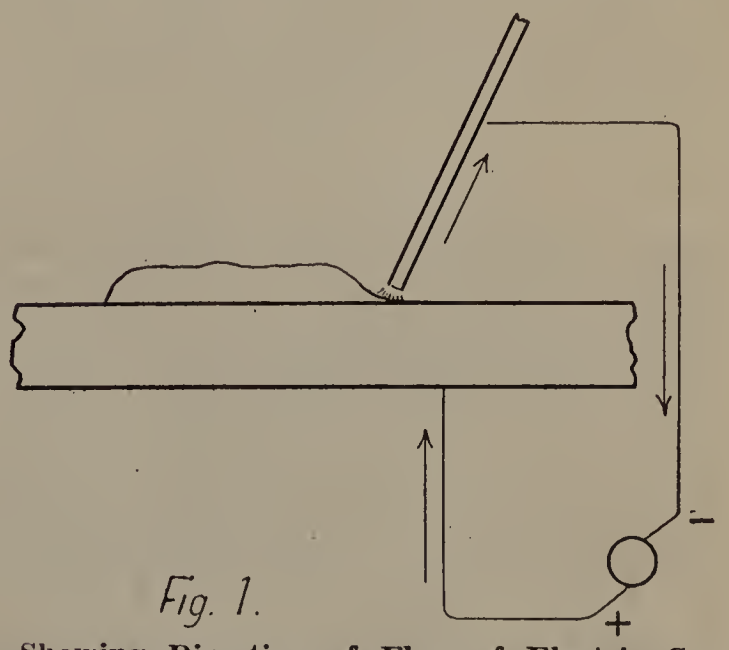


Zens Welding Transformer

coil, which is raised or lowered to decrease or increase the flow of current for requirements. This adjustment is accomplished by means of a handwheel, pinion and the rack to which the secondary is attached. Based on a transformer efficiency rating of 98 per cent the efficiency of this machine is given as about 90 per cent.

METAL ELECTRODE WELDING

When the filling rod in electric arc welding is used as one electrode the process is called metal electrode welding. When direct current is used the work on which metal is to be deposited is generally connected to the



Showing Direction of Flow of Electric Current, Angle of Electrode and Length of Arc in Metal Electrode Welding.

positive side of the welding circuit and the metal electrode to the negative side of the circuit. Owing to the fact that the greater part of the heat is produced at the positive electrode this keeps a puddle of metal on the piece being welded so that molten metal from the metal electrode will be received on

the piece at a point at which the metal is molten. When alternating current is used either terminal may be connected to the work. **Welding can only take place when molten metal from the electrode falls on molten metal of the piece.** If the connection were reversed and the largest amount of heat produced on the metal electrode, rather

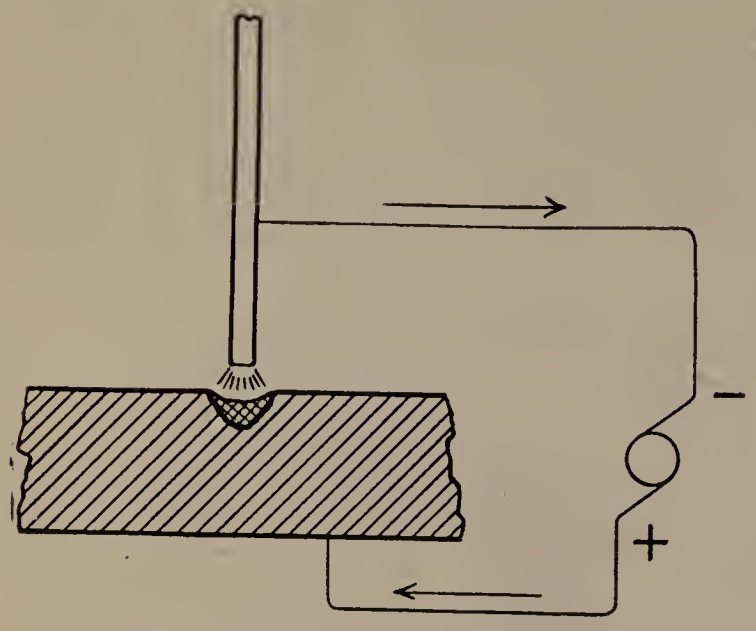


Fig. 2.

Cross Section of Crater Showing Crater Surface and Depth of Melting or Penetration.

than on the piece, the tendency would be for molten metal from the electrode to fall on metal on the piece which is not molten and, therefore, no weld would result. It should be kept in mind that this is a tendency and not a rule for it is true that if the polarity is reversed some welding will take place, but in general it will not be as complete as if the work were made positive and the electrode negative. Fig. 1 and 2.

The exception to the rule of connecting the work to the positive side of the circuit and the electrode to the negative side is the case in which bare wire electrodes such as

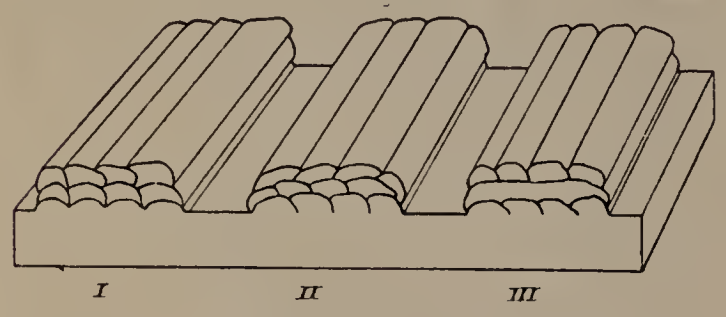


Fig. 3

Show Correct and Incorrect Welding Patterns. Building Up Pads.
I. Slag Line Between Parallel Beads, Continuous in Vertical Plane.
II. Staggered Parallel Beads.
III. Correct Pattern with Second Layer of Beads at Right Angles to First Layer.

12 per cent manganese steel or 1 per cent carbon, are used. Also in the case of the very heavily slag coated electrode. In the case of the bare wire electrode referred to it is found that it is quite impossible to use the electrode bare with the proper polarity. By reversing the polarity fair results may be obtained. However, the arc with the proper polarity is extremely "wild" and difficult to manipulate and this difficulty is decreased by reversing the polarity. In the case of the heavily slag coated electrode the practice of making the electrode positive is presumed to rest on the theory that the heavy coating of slag around the molten metal of the piece is sufficient to conserve the heat at this point so that with the additional heat being transferred across the arc by the flow of molten metal from the electrode a sufficient amount of heat is brought to bear upon the point at which fusion is to be accomplished to yield the proper results.

In manual operation of the metal electrode

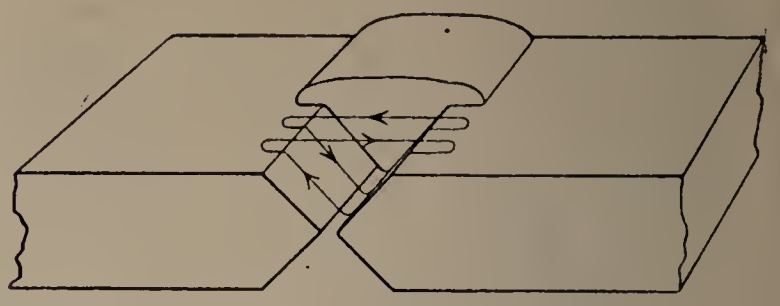


Fig 4

Correct Pattern for Welding One Side of Double Bevel Joint. Note Direction Reversed on Alternate Patterns.

process there are three essential motions which the operator executes in depositing metal. First, the continuous downward feeding of the electrode to compensate for the metal which is melted off the end of the electrode. Second, the advancing motion of the electrode to deposit the metal in a predetermined "bead." Third, the sidewise or lateral motion given the electrode for the purpose of puddling the molten metal.

Referring again to the fundamental law that a weld may only be accomplished when

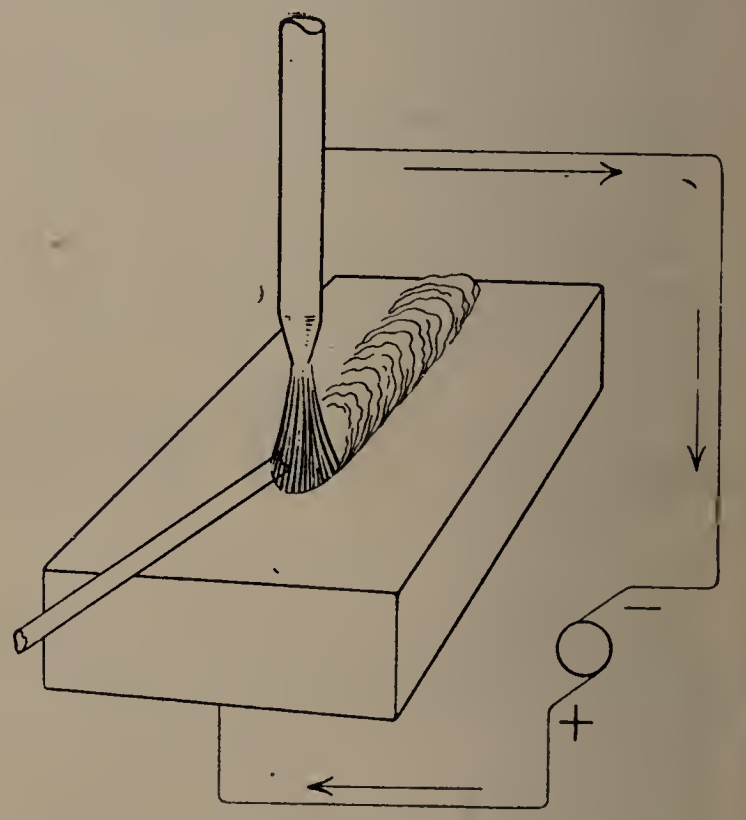


Fig. 5

Carbon Arc Welding Showing Position of Electrode, Melt Bar and Distribution of Arc Flame.

molten metal from the electrode falls on molten metal of the piece, it is evident that the electrode must be held sufficiently close to the work so that the molten metal from the electrode will be transferred directly and with positive accuracy into the molten metal in the "crater" of molten metal on the piece. If the operator holds a long arc a considerable portion of the metal from the electrode will be deposited outside of the molten "crater" on the piece and it is true, of course, that this metal will not be welded to the piece. The point has also been raised about the use of a long arc resulting in burning the metal as it passes from the electrode to the piece. This theory is discussed at length at end of this chapter, under the heading "Oxidation Within the Arc."

The discussion should be read carefully, as it has an important bearing on the operator's work.

Metal which has passed through what is ordinarily called a long arc "from $\frac{3}{16}$ to ¼ inch long" exhibits the same characteristic as metal which has passed through an arc as short as ⅛ inch. However, a weld made with a long arc shows striking evidence of poor fusion owing to the fact that molten metal has not come in contact with molten metal of the piece, and of oxidation, as mentioned above.

The various types and kinds of apparatus are sometimes referred to as long arc or short arc machines. This terminology has been misleading due to the fact that any arc which may be used for commercial welding purposes may be held so long that an unsatisfactory weld will be the result. The characteristic referred to in the terminology is the character of the arc when it is suddenly lengthened. The type arc referred to as a short arc machine is one which upon sudden lengthening will break. The so called

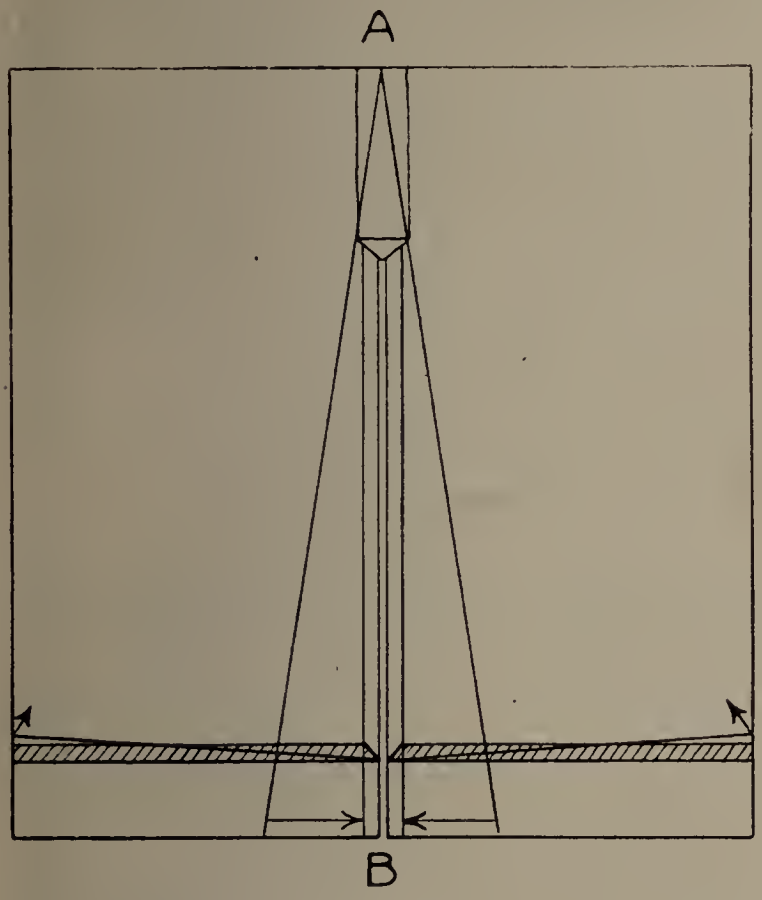


Fig. 6.

Graphic Representation of Contraction Tending to Pull Plates Together and Out of a Horizontal Plane During the Welding Operation when Joint Is Welded from A to B Continuously.

long arc is the kind of an arc that will permit the operator to suddenly lengthen the arc without having it break.

It is a fundamental rule of electric arc welding that any welded joint should be accomplished with the minimum amount of added material between the ends of the pieces being jointed. The reason for this rule of practice lies in the fact that metal which has passed through the arc lacks the normal degree of resiliency and ductility. In other words, it is inferior to normal cast steel or normal rolled steel in the matter of ductility. The edges of the pieces welded together should be as close together as possible and still permit manipulation of the arc to get perfect fusion.

In a piece to be welded which will have a bending stress applied in such a manner as to tend to bend the welded joint, the welded joint should always be made stiffer than the original section so that bending will come outside of the welded joint. This is a fundamental rule of applying the welding process since the ordinary commercial weld made by the metal electrode process will not stand bending owing to its lack of ductility.

Assuming perfect fusion between the added metal and the metal of the original piece, the strength of the weld will depend upon the amount of slag inclusion in the weld. The greater the extent of slag inclusion the weaker in general will be the weld. Good welding practice demands that all the slag which consists principally of mill scale (or black oxide) be frequently removed from the weld as the welding process continues. In the case of the use of heavily covered electrode, it is of course absolutely necessary to remove the slag and oxide from each layer of metal before the succeeding layer is deposited.

It is evident also that the surfaces upon which the welding is to be done must also be clean before welding is done in order to get the best results. The presence of oil on the surface to be welded is far more serious than the presence of a red iron oxide, since the oil not only interferes with the stability of the arc, but also upon being burnt introduces a sufficient amount of car-

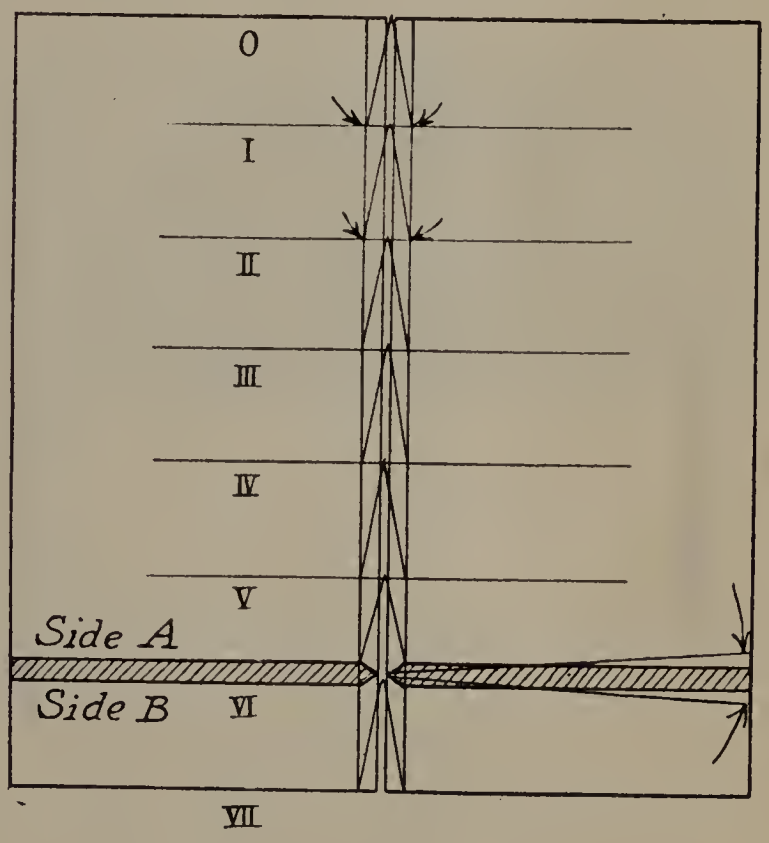


Fig. 7

Rigid System of Welding Plates Method of Minimizing Effect of Contraction.

Procedure:—Weld from	**VI**	**to**	**VII**	**from Side A.**
Procedure:—Weld from	**V**	**to**	**VI**	**from Side B.**
Procedure:—Weld from	**IV**	**to**	**V**	**from Side A.**
Procedure:—Weld from	**III**	**to**	**IV**	**from Side B.**
Procedure:—Weld from	**II**	**to**	**III**	**from Side A.**
Procedure:—Weld from	**I**	**to**	**II**	**from Side B.**
Procedure:—Weld from	**0**	**to**	**I**	**from Side A.**
Procedure:—Weld from	**VI**	**to**	**VII**	**from Side B.**
Procedure:—Weld from	**V**	**to**	**VI**	**from Side A.**
Procedure:—Weld from	**IV**	**to**	**V**	**from Side B.**
Procedure:—Weld from	**III**	**to**	**IV**	**from Side A.**
Procedure:—Weld from	**II**	**to**	**III**	**from Side B.**
Procedure:—Weld from	**I**	**to**	**II**	**from Side A.**
Procedure:—Weld from	**0**	**to**	**I**	**from Side B.**

bon into the metal to materially increase its hardness. Oil and grease should be removed from a surface to be welded by brushing the surface with dry lime or by immersing the part in a strong alkaline solution. The presence of acids on a surface also interferes with the stability of the arc. Black oxide of iron being a very poor conductor of electricity interferes seriously with metal electrode welding.

The best results with metal electrode welding are obtained when the welding is done according to a predetermined pattern. Metal

deposited according to a predetermined pattern is less likely to exhibit continuous slag lines which weaken materially the welded material. Fig. 3 and 4.

The amount of metal which can be deposited per hour by the metal electrode process depends upon the following factors:

First, the amount of heat used; second, the continuity of the heat, that is the number of minutes per hour that the arc is actually in operation; third, the nature of the metal being melted and deposited; fourth, the size of the piece upon which the metal is being deposited.

In general the latter two factors may be neglected since the variation due to these factors is small in comparison with the variation due to the first two factors. In ordinary practice with manual operation of the arc the amount of metal deposited varies from one to four pounds per hour.

Automatic Welding

Depositing metal by the metal electrode process, using an automatic feed for the electrode results in a materially increased rate of depositation. This method of depositing metal by the metal electrode process

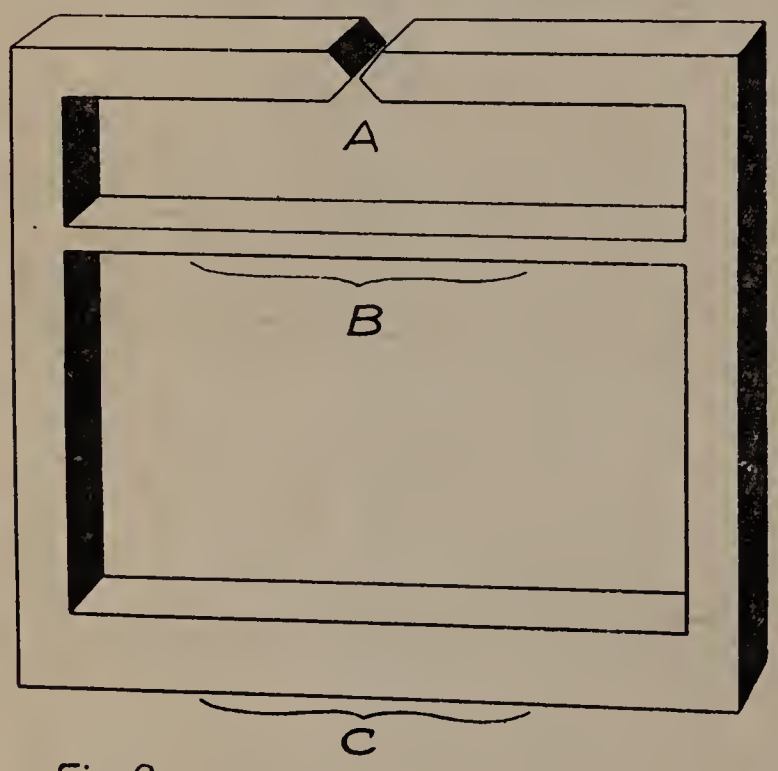


Fig. 8.

Heat Application to Compensate Contraction Due to Welding Heavy Cast Iron Section with Carbon Arc.
Procedure:
1. Heat B and C to Same Temperature.
2. Complete Weld at A from Alternate Sides.
3. When A, B and C Reach Same Temperature Allow the Three Sections to Cool at the Same Rate.

is particularly advantageous on sections of uniform shape upon which a considerable amount of metal is to be deposited. It is also of great utility where welding is to be done on thin sections or work of a continuous nature wherever the amount of current which can be used is so small that the work cannot be done manually due to the fact that it is impossible for the human hand to hold the arc steadily enough to get the desired results.

Automatic welding does not eliminate the human factor in welding, but does in certain cases tremendously increase the speed of the process, and in other cases accomplishes results which are beyond the limitation of manual operation. See "Automatic Arc Welding" at end of this chapter.

CARBON ELECTRODE WELDING

The difference between carbon electrode welding and metal electrode welding arises from the fact that the arc is drawn between carbon electrode and the work and also that the filling rod is fed into the arc separately, that it does not carry the arc's current as is the case in metal electrode welding. Carbon electrode welding practice is in every way similar to welding with the oxy-acetylene flame. The carbon arc may be used for welding in which no metal is added, preheating, and to a limited extent. for cutting purposes. Fig. 5.

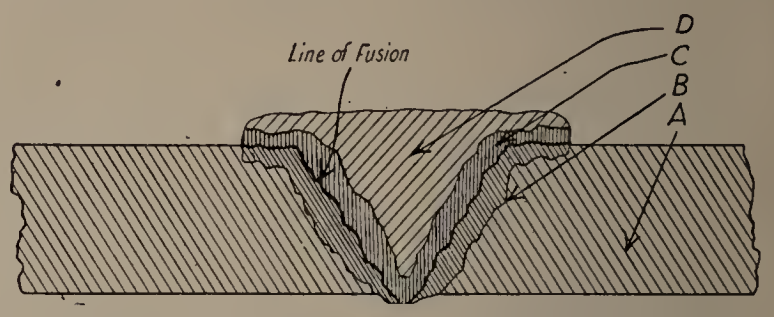


Fig. 9.
Showing Effect of Heat on the Metals; Welding Cast Iron with Steel Electrode.
A—Original Cast Iron.
B—Cast Iron Which Has Been Hardened.
C—Steel Hardened by Absorption of Carbon.
D—Steel Deposited But Unaffected.

When a carbon electrode is used, the carbon is always put on the negative side of the arc. When the carbon electrode is on the positive side of the welding circuit the arc is extremely unstable. Another serious disadvantage of making the carbon positive from the welding point of view arises from the fact that the arc is always maintained in the vapor of the positive electrode. In the welding of steel by the carbon process, therefore, if the carbon electrode is made positive, the carbon monoxide comes in contact with the molten steel and is absorbed, thus carbonizing the steel rapidly and invariably resulting in a hard weld.

In several cases the feeding of the carbon electrode in this application is done mechanically, and feeds as high as 400 feet per hour have been reached, making a weld in this manner. In manual operations a speed of 120 feet per hour is about the highest speed which can be maintained. By increasing the amount of current in the arc circuit and driving the electrode mechanically, both the speed of doing the work and the appearance of the job when completed are materially improved.

Carbon electrode welding is used commerically, almost exclusively in the steel foundry, where defects in steel castings are to be corrected. On this application currents in the arc as high as 600 amperes are used, although some work is done with a current as low as 250 amperes. The size of filling rod used depends on the amount of current being used in the arc circuit.

The one steel foundry job which is done more satisfactorily by the electric arc than by any other means so far applied to the

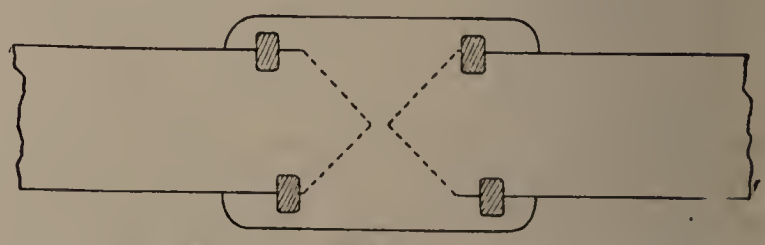


Fig. 10.
Use of Staggered Studs for Cast Iron Welding with Steel Electrode.

work is in the burning out of a bad sand spot. In this case the casting is set up in such a manner as to permit the molten metal to flow freely from the defective spot, and the arc applied until all of the defective material is melted away. Then a filling rod is used after the casting has been turned so that the weld appears in the horizontal position, and new metal filled in where the defective metal has been burned out. The

difficulty experienced in the application of the gas torch to such a job is due to the serious overheating of the tip due to the fact that the flame is directed perpendicularly towards the surface to be melted. In the application of the arc welding process to steel castings trouble frequently occurs due to hard spots in the weld after it is completed. These hard spots are due usually to one of two causes. First, if the operator accidentally breaks the arc and dips the hot carbon electrode into the puddle of molten metal sufficient carbon will be transferred into the molten metal to carbonize it to such an extent that upon cooling it will be hard. The proper practice is to start the arc on solid cold metal and bring it over to the molten metal from that point.

On a casting rather high in carbon and manganese, if a small defect is corrected by the arc process, and the operator does not play the arc around in the vicinity of its defects sufficiently to introduce enough heat into the casting to prevent sudden chilling of the welded spot the welded spot will be hard. The solution of this difficulty is to use the arc as a pre-heating agent, either just before, or just after the welding operation is completed.

A steel foundry making small steel castings averaging 50 pounds requires approximately 300 amperes welding capacity, per operator. The steel foundry making very

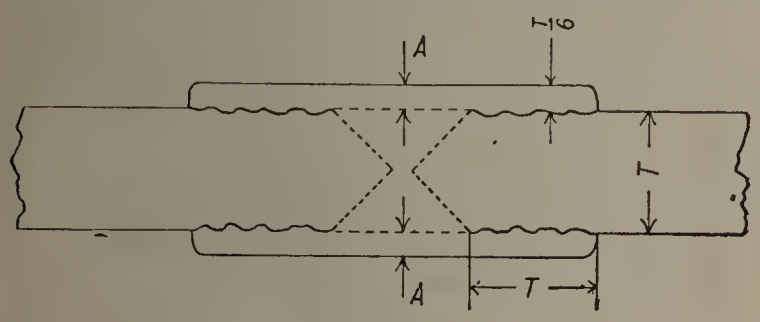


Fig. 11.
Welding Cast Iron with Steel Electrode without Studs, Showing Section of Weld. Sections A-A, Owing to Higher Tensile Strength of Steel Arc Equivalent to Tensile Strength of Section T.

heavy steel castings, such as railroad material requires, approximately 600 amperes per operator welding capacity. While it is true that as high as a thousand amperes can be used on steel castings, balancing the advantage in time gained on such jobs against the initial investment required to install that capacity, it is evident that 600 amperes per operator is the most economical amount of capacity to install on this work. The carbon electrode welding process is used to a limited extent in the welding of gray iron. The carbon arc used on gray iron is identical in every respect to the use of the gas torch, for the same purpose. The difficulty encountered in the use of carbon arc for cast iron welding arises from the fact that the temperature of the arc cannot be controlled although the amount of heat can be regulated to a great degree of precision, so that the operator has to either use the full temperature or break the arc. The net result of this difficulty is that a considerable amount of skill is required to make a weld where the surface being welded is in a vertical or inclined position, due to the tendency of the hot cast iron to run out of the weld. The use of carbon paste and carbon molds, partially eliminates the difficulty, but under the most favorable conditions it is more difficult to make a cast iron weld with a carbon arc, than it would be using the oxy-acetylene flame. The same factor in the carbon arc welding enters into the welding of cast iron even in a horizontal position, when the section of the cast iron is thin. The tendency is for the arc to burn through the cast iron before the operator can complete the weld.

As a tool for cutting the carbon arc has a rather limited use. The arc does not cut in the sense that an oxygen stream does when directed upon steel. In the case of the carbon arc, it is merely a proposition of melting a crevice through the parts to be cut and the result is a ragged cut. In addition to the irregular appearance of the cut a considerable amount of metal is wasted due to the width of the cut. However, where large quantities of steel and cast iron are to be cut for scrap purposes, the carbon arc offers the advantage of lower cost of operation than the gas cutting torch. However at the present time the carbon arc is not used to any great extent commercially for such work except in rivet cutting.

Protection of the Operator

The rays of the electric arc are of such a high degree of intensity that the naked eye or the skin must not be exposed to them within 20 feet of the point at which the arc is in operation. The rays of the electric arc are no more injurious than the rays from the sunlight of the same intensity. Injuries caused by the light of the arc are due to the intensity of the light and not to

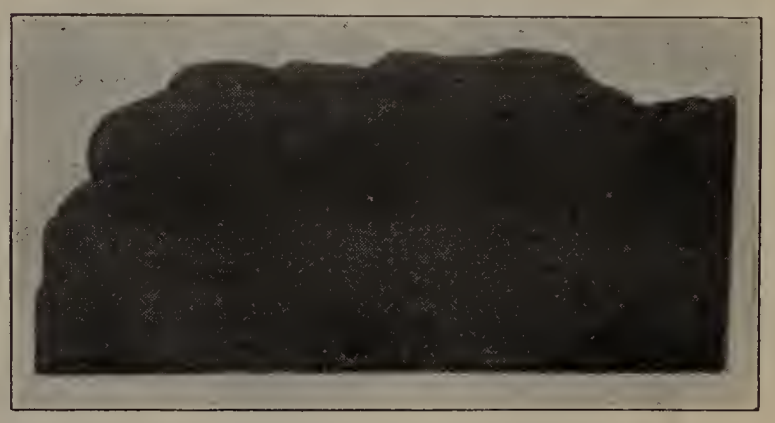


Fig. 12.
Section Through Weld.

its composition. The effect of exposure tc the light of the arc is in every respect similar to sunburn, and while the effect may be painful, it is temporary and no case is on record in which any one has been permanently injured by the rays of an electric arc, used for welding purposes. The operator looks at the arc through colored protective glasses. Recently, however, optical experts have produced a pigmented glass of the proper shade to protect the operator using only a single thickness of the glass. This glass is produced in several shades of yellow brown, and permits considerably better vision of what is going on in the arc by the operator, at the same time protecting him entirely against the great intensity of the light. The color of the glass is designed to eliminate entirely the ultra-violet and infra-red portions of the spectrum. This glass is considered by most operators to be superior to the old color combination of glasses.

Where the operator must use both hands as in the carbon electrode process, and in metal electrode welding as applied to overhead work, he wears a head shield, while for ordinary horizontal welding, using the metal electrode process, he usually uses only a face shield which he holds in his left hand.

Protection of Workmen

The walls of any enclosure in which electric arc welding is done should be painted a flat black, so that the effect of reflection is reduced to a minimum. An operator may be severely burned by reflections from a bright surface on the back of his neck and on the back of his ears.

In addition to protection of operator's eyes and skin from the injurious effects of the arc rays, it is recommended that

adjacent workmen be protected by coating walls and ceilings with a paint which will not reflect ultra-violet rays. It has been found that paint for this purpose can be made with zinc oxide, toned down slightly with lampblack, and mixed with glue water, so as to give a smooth surface.

Where operators are using the electric arc, in an open shop or where other men are working it is the usual practice to provide light portable screens so that the light of the arc will not interfere with other men working in the vicinity. The use of an electric arc on an open floor which is served by cranes does not conform with the safety first rules of most institutions, the reason being that the flashing of the intense light of the arc is disconcerting to the crane operators and may cause serious accidents.

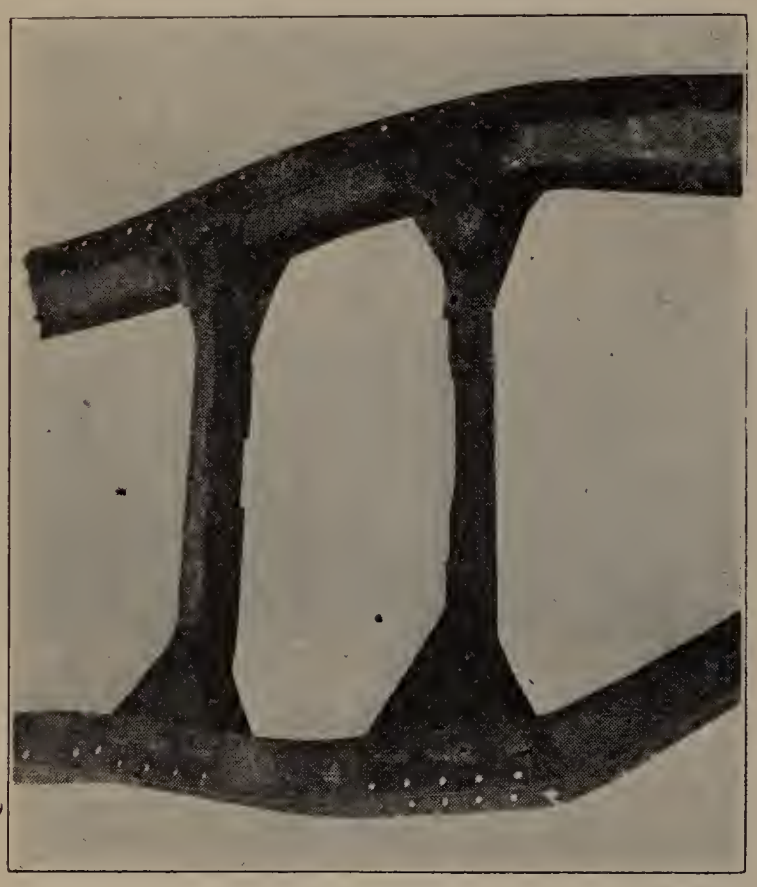


Fig. 13.

Automobile Truck Frame, Originally Designed for Riveting, Gusset Plates Welded. After Destructive Test Showing Failure in Rivet Holes. No Failure in Welds.

ARC WELDING APPLICATIONS

Welding of Rolled Steel and Wrought Iron

The application of electric arc welding to steel or wrought iron structures and pieces is one which should be made with a full knowledge of the limitations of the process. Practically no commercial applications have been made of the carbon electrode welding process to these classes of metal, so that what is to follow applies entirely to the metal electrode process.

The fundamental factors which should be considered in the application of the metal electrode welding process to rolled steel and wrought iron are as follows:

The tensile strength of the metal fused into the joint, assuming that the fusion is perfect will be in the neighborhood of 80% of the tensile strength of the original electrode used. If a dead soft steel or iron electrode is used having an initial tensile strength of approximately 50,000 pounds, the maximum strength which can be expected from this metal in the weld will not exceed 40,000 pounds per square inch. From a steel electrode having a considerable percentage of carbon and manganese, and possibly nickel, which may have an initial tensile strength of approximately 80,000 pounds per square inch of area we may expect a tensile strength of the metal in the weld of approximately 64,000 pounds per square inch. The ductility of the metal in the weld made commercially by either the bare wire or covered electrode may be considered as a negligible quantity. Third—the metal added by the welding process, and the metal of the original pieces adjacent to the line of fusion will be in the nature of cast metal after the welding process has been completed. Due to the puddling process during the welding operation and the fact that the metal has been molten, all of the effects of mechanical treatment on the electrode and on the original pieces in the immediate vicinity of the weld have been entirely eliminated. While the thermal effect does not extend as a rule beyond $\frac{3}{16}$-in. from the line of fusion into the metal of the pieces which

Fig. 14.

Broken Spider on Large Alternator Welded with Steel Electrodes without Studs.

have been welded, the fact remains that the metal affected has been changed from rolled metal into cast metal in this area. Fourth—the percentage of fusion will depend entirely upon the operator who makes the welds. The amount of fusion in the weld may vary from 50 to 100% depending upon how skillfully he manipulates the arc and whether or not the metal being deposited is free from slag and oxide inclusion. Fifth—in steam boilers and other vessels, subjected to pressure, the welds may be tested, but in structural steel construction as a rule a test is impractical. However, with proper engineering supervision and inspection of the welding while the operation is being done, complete reliance may be placed upon an approved weld.

With these fundamental considerations in mind, the application of the process can be made with perfect safety. The point has already been made that a weld which is to be subjected to a bending stress must be made stiffer than the sections of the structure adjacent so that any bending will come entirely outside of the weld.

The resistance of the welded material to high frequency, alternating stresses is a factor upon which little data is available, but there is reason to believe that the resistance of the welded material to such stresses is considerably lower than would be expected from commercial rolled steel sections. The resistance of the welded material

to shear is usually assumed to be 8/10 of its strength in tension.

The welded material is usually assumed to have the same strength in tension as in compression. The hardness of the metal deposited by the metal electrode process on mild steel plate and wrought iron where a mild steel electrode is used is from 10 to 15% greater than the hardness of the original section. This difference in hardness does not affect the machinability of the metal seriously, nor does it affect the use of a chipping tool. The use of high tensile strength electrode in order to obtain high tensile strength of the metal of the weld is seldom encountered in commercial work, since the brittleness of the metal increases rapidly with the tensile strength and the high tensile strength electric weld is of little value due to this cause. The application of the electric arc welding process, to

Fig. 16.
Welding Replaces Riveting with Saving of Time and Labor.

the welding of rolled steel sections and of wrought iron may be made with perfect safety, in a large variety of cases, if the fundamental limitations of the process are kept well in mind, but as is the case with any one of a number of new processes, there is danger that the enthusiast will attempt to make applications of the process without due regard to its limitations.

Welding Cast Steel

The fundamental principles stated with reference to the welding of rolled steel and wrought iron hold in the case of the welding of cast steel. However in the commercial application of the process, the welding of cast steel, somewhat different problems are encountered owing to the nature of the welding work to be done on steel castings.

The use of the carbon arc on steel castings has been referred to in detail. A comparatively small percentage of the total electric arc welding done on steel castings outside of the steel foundry is done with the carbon-arc process. The reason for this is that it is not generally considered to be good practice to apply the carbon arc process or the oxy-acetylene welding process to a steel casting, if it is not to be subsequently annealed to remove the internal strain set up by the welding process. The application may be made to steel castings with either the carbon arc or oxy-acetylene process, if the expansion and contraction of the metal during the welding process is taken into account, and such measures as might be necessary, taken to prevent internal strains in the casting, after the welding operation is complete. The metal electrode process offers the easiest solution to the welding of cast steel for the reason that the effect of expansion and contraction of the metal is minimized with this process. It is never necessary to pre-heat a casting if the welding is to be done by the metal electrode process. It is never necessary to subsequently anneal a steel casting which has been welded by the metal electrode process, due to internal strain.

Since the class of steel castings which are broken, and which are brought to the Electric Arc Welding Machine to be welded, are usually of a very heavy section, the matter of preparation of the pieces for the welding operation and the regulation of the practice to minimize the effect of expansion and contraction are factors which must receive consideration. In the matter of preparation of the job for welding, the fundamental principle upon which all preparation must be based is that **the welding must be completed, with a minimum amount of metal between the fractured edges.** The ideal condition has

Fig. 15.
Welding Has Replaced Riveting Here.

been reached when the bevel between the edges, is just sufficient to permit the operator to manipulate the arc in such a manner as to get perfect fusion. If the bevel is too wide an angle, the weld will be weakened by virtue of the fact that, the more metal added by the metal electrode process, layer on layer, the greater is accumulation of slag inclusion in the metal so deposited, and the lower its quality. On the other hand if the angle of bevel is too narrow the weld will suffer due to poor fusion. The bevel should be made on both sides of the joint, to conform with the general principle that the minimum amount of metal should be added between the edges, of the fractured piece.

In a very complicated and thin section the heat should be distributed as widely as possible, and in extreme cases the welding operation should be carried on intermittently to allow the heat to distribute itself over the pieces, being welded so that a sufficient amount of heat is not concentrated at one point to cause undue or harmful expansion of the metal.

In the welding of cast steel it is frequently an advantage to use an electrode which is considerably harder than the metal of the original pieces being welded. This applies where the surface of a steel casting is subjected to unusually severe wearing service. In this case the electrode may be 1% carbon steel, 12% manganese steel, or gray iron. In the latter case in which the operator uses a gray iron welding rod. if the section is sufficiently heavy the chilling action on the cast iron as it is deposited on the steel casting will change it to white iron which is extremely hard. Metal deposited using a hard electrode cannot be machined and must be ground with an emery wheel. A hard surface may be welded on to a steel casting. regardless of whether the steel casting itself is soft or hard. In the case of the man-

ganese steel casting used in railway cross-overs, welding is done using either the 1% carbon and steel electrode, or 12% manganese steel electrode with satisfactory results. The work is done with the bare or covered electrode, although the covered electrode offers an easier solution to getting the maximum degree of hardness. Using the bare electrode the proper degree of hardness can be obtained, but great difficulty is experienced in getting the proper degree of fusion owing to the fact that the hard steel electrodes do not work well in the arc, without a covering.

Wherever possible a weld made in a steel casting should be reinforced so that the section of the weld is greater than the original adjacent section. This is due to the low degree of ductility as compared with the ductility of the original casting. The weld wherever possible should be made stronger than the original section.

Cast steel is generally presumed to have less resistance to "fatigue" than rolled steel. It has been observed that castings subjected to high frequency, alternating stresses will deliver perfect service for a given length of time. The initial failure due to breakage, is corrected by the welding process, but in a comparatively short length of time, another failure will occur in some other part of the casting and the subsequent history of the casting will show a continuous record of failures due to breakage. The most logical explanation to a case of this kind is that at the time of initial failure, the metal of the casting had undergone its limit of fatigue. If after the initial failure had been welded the casting had been annealed, the later failures would probably have been eliminated. Steel castings which have been repeatedly subjected to high temperatures, frequently cannot be welded. This occurs particularly in the case of annealing pots, and annealing boxes. In such a case it is impossible to get a reasonable degree of fusion between the added metal and the metal of the original piece.

Welding of Malleable Iron

From the practical welding point of view malleable iron may be considered as gray iron having a skin of soft iron. The thickness of the skin varies widely, and depends upon the length of time the casting was annealed in its manufacturing process. The quality of the malleable casting is usually determined by the depth of this soft skin.

Welding on malleable iron is always done with the metal-electrode process in order to localize the heat to as great an extent as possible and avoid hardening of the core of the casting. Malleable iron having a deep skin and practically no core, can be welded with the metal electrode process using the mild steel electrode giving a weld which is stronger in section than the original casting. However, the casting which has been welded will not stand any bending through the welded section. By making the section of the weld stronger than the adjacent section of the original casting, the bending can be made to occur entirely outside of the weld.

In a malleable iron foundry where small defects are repaired by the metal electrode process, if the casting is to be subsequently machined, the casting is put through the annealing process a second time after the welding has been completed. Welding of malleable iron castings, before they have been put through the annealing process has never been successful, owing to the fact that the castings before they are annealed are white iron and will crack upon application of the localized heat of the arc.

Welding Gray Iron

Gray iron, or what is commonly called cast iron offers the greatest difficulty to the welding operator of any metal he has to weld commercially. Cast iron owing to its low cost is more extensively used for the building of machines, than any other metal. Now the designer of a machine which is to be built of cast iron usually attempts to make the cast iron sections so thick and stiff that any likely bending stress will be successfully resisted. However, owing to the fact that cast iron has no ductility, and an inappreciable degree of elasticity, the number of breaks in gray iron castings is extremely high. However due to the wide spread use of gray iron castings, and the tremendous economic saving possible, where the castings can be welded, the problem of welding cast iron is perhaps the most important one in the application of the welding process.

A large number of cast iron welding jobs of the nature illustrated in the accompanying cut have been done successfully. In this class of work the metal electrode process is used, using a dead soft steel or iron electrode. The advantage of this practice lies in the fact that the welding can be done without pre-heating. Oftentimes, a heavy casting can be welded in place, thus saving the cost of taking it off and preheating it, as would be necessary if the carbon arc or oxy-acetylene flame were used.

The difficulty in getting a strong weld using the steel electrode on cast iron arises from the metallurgical character of the cast iron. Sketch in Fig. 9 shows the points referred to in this discussion. On the cast iron side of the line of fusion, the cast iron which has been melted in order to accomplish fusion with the steel which has been added is chilled by the mass of cold metal of the piece, and the result is a metal which is extremely hard and brittle. This hardening is due to the fact that the rapid cooling prevents the iron carbide from changing into iron and graphite and the heat of welding has burned out the carbon and silicon to the extent that the iron chills more easily. The metal in this area is white iron. The controlling component being cementite. On the steel side of the line of fusion, there is a marked increase in hardness in the steel, due to the absorption of carbon from the cast iron. In fact the first layer of steel has been changed from a mild steel to a rather high carbon steel by this process. Failure of a welded joint of the type illustrated in the illustration—if fusion is perfect, will usually occur in the cast iron adjacent to the line of fusion, because the hardened cast iron is more brittle than the high carbon steel on the steel side of the line of fusion, as well as the original cast iron.

In practice the operator welds the steel on to the cast iron, by an intermittent process, allowing the heat to be distributed throughout the metal thus avoiding insofar as is possible the contraction strains which would tend to tear the steel away from the cast iron. Owing to the fact that steel contracts a greater percentage of its initial dimension, upon cooling through a given temperature range, than cast iron, unless the welding is done intermittently, and the operator avoids localizing too much heat on the cast iron, he will experience the trouble due to the steel pulling away from the cast iron.

Figure 10 shows the use of studs and grooves in order to increase the total strength of the weld made, using steel electrode on cast iron. This practice is frequently used in the welding of heavy cast iron sections.

Figure 11 shows a method of making a cast iron weld with the use of steel electrode without the use of studs, which accomplishes the purpose by putting the junction between the steel and cast iron in shear rather than in tension.

Fig. 12 shows photographic reproduction of section through such a weld, and indicates why the steel reinforcing does not tear away from the cast iron regardless of the amount of fusion.

The metal electrode process, the using of steel electrode has not been used extensively

in the commercial field, for the welding of cast iron sections thinner than a quarter of an inch, owing to the tendency of the great localization of the heat to crack the casting. Extensive work has been done with the metal electrode process, welding heavy cast iron sections with a surprising degree of success. The tendency of the more conservative engineers, however, has been to avoid the application on a casting the failure of which would bring death or great destruction, in case there is no method of testing the quality of the weld, prior to putting the casting into such hazardous service.

The Welding of Copper

No extensive application of the electric arc process has been made in the welding of copper to copper. Such work as has been done, has been done exclusively with the carbon arc, using the arc merely as a source of welding heat. Covered electrodes, however, give promise of an advance in this line.

The difficulty encountered in welding copper which has had mechanical treatment, arises from the fact that the copper is changed from a rolled metal to one which has the characteristics of cast copper, so that the metal in the weld is extremely brittle and has no appreciable degree of ductility.

Some work has been donc in the electrical industry using the copper to copper welded joints for an electrical connection. In this application, however, the weld is always subjected to a shearing stress and is not required to resist bending stress.

The most important application of the carbon arc process to the welding of copper is in the application of copper bonds to street railway tracks. In this application the end of the bond, is fitted with a copper lug and the copper of the lug is fused to the steel of the rail by the use of the carbon arc. The welded joint is electrically perfect and since it is not subjected to a severe mechanical strain, the brittleness of the weld is not an objectionable feature.

Welding of Bronze

The welding of bronze with the metal electrode process using a bronze electrode, has been successfully done for several years. While it is practically impossible to get 100% fusion using bronze electrode on bronze work, in several applications a sufficient amount of fusion is obtained to give a satisfactory job. The propeller shaft sleeve of a ship is usually made of bronze, and owing to the fact that it runs through a stuffing box is subjected to rather rapid wear. These propeller shaft sleeves are built up using the metal electrode process, and bronze wire. Another application which has been made successfully is on the repair of bronze impeller wheels used in water driven turbines. The erosion of the water causes rapid deterioration of these wheels and the arc welding process has been used successfully to build in new material, where the water has worn away the original material of the wheel.

Welding of Brass and Aluminum

The electric arc process has never been applied with any commercial degree of success in the welding of aluminum and brass. The difficulty arises from the fact that the temperature of the electric arc is too high to weld these metals on a commercial basis.

Expansion and Contraction

The engineer or craftsman using the electric arc welding process finds that expansion and contraction of the metal during the welding operation is a matter which must be considered in a large number of cases. While difficulties encountered are not so serious as those encountered in the application of the oxy-acetylene process, due to the much greater localization of the heat, in a good many cases the problem is one which should not be neglected.

In application of the carbon arc process, the expansion and contraction problem is handled in exactly the same manner as if the job were to be done by the oxy-acetylene process. The operator always plans to preheat the job so that the crack or opening to be filled in by the welding process will be opened by the effect of the pre-heating. When the job is being cooled after the welding operation is completed, the welded section together with the pre-heated section should be kept at the same temperature, until the job is completely cooled, if the preheating were local. In the cases of complicated castings, where it is impossible to preheat locally, the operator will pre-heat the whole casting, then put the casting back to be heated again after the welding operation is completed to permit the various members of the structure to conform to the new conditions brought about by the introduction of the welds.

In the application of the metal electrode process, pre-heating is seldom done. Difficulties, however, are often experienced, due to the fact that the metal in the joint is at a much higher temperature than the metal surrounding it. Upon contraction the tendency is to put an undue strain at some point in the structure which may or may not be in the weld. Various methods are used to overcome this ever present difficulty. All methods however can be grouped under one or two plans. First where possible design the structure being welded to permit it to be deformed without being damaged, when the contractional force is brought to bear upon its part. Second—where the shape of the members of the structure cannot be altered, the solution is to distribute the total heat as widely as possible, during the welding operation and to avoid so far as possible, localizing a considerable amount of heat at any given point. Fig. 6 and 7.

Assuming that the arc is producing a given amount of heat, the amount of expansion by the structure being welded at a given point will depend upon the length of time the arc is in operation at that point. The amount of expansion at that point will depend entirely upon the amount of heat applied to that point of the structure. The contraction will be equal in amount to the expansion, it being assumed that no internal strain is left. It is evident, therefore, that the total expansion on contraction tending to deform the pieces being welded will be less if 100 B. T. U. per hour, is applied at a given point than if heat is applied at the rate of 1,000 B. T. U. per hour. The total expansion or contraction depends upon the amount of heat applied, and in general the lower the amount of heat applied to a welded seam, the smaller will be the expansion and contraction effect. Fig. 8.

THE COST OF ARC WELDING

The widespread and growing use of the electric arc welding process has been due primarily to the low cost of applying the process. While some of the applications are not possible with any other process the underlying factors in its development are economic rather than technical.

There are three contributing factors which make the process cheaper than some of the other processes.

1. Heat produced by the transformation of electric power into heat costs less per B. T. U. than that produced by the oxy-acetylene flame.

2. The heat produced by the electric arc can be utilized more economically than heat produced by the combustion flame, due to the fact that it is produced in the metal by the arc process rather than external to it. One B. T. U. produced by the arc will do more welding than one B. T. U. produced by the combustion flame.

3. The heat of the arc may be more easily applied than the heat otherwise produced.

The statements above are general and apply only to work which can be done equally well by the arc and combustion flame processes.

The cost of doing electric arc welding with the metal electrode process depends upon several variable factors.

1. The willingness of the operator
   (a) The price of labor.
2. The characteristic of the arc.
   (a) Arc easy to maintain.
   (b) Arc difficult to maintain.
   (c) Amount of heat available.
3. The cost of power.
   (a) Efficient machine.
   (b) Inefficient machine.
   (c) The kilowatt rate
4. The cost of electrodes.
   (a) Covered electrode.
   (b) Bare wire.
5. Supervision required.
   (a) Production work.
   (b) Each job different.
6. Interest charge on equipment.

A hypothetical case will be analyzed to show the effect of variation of these factors:

Operators "A" and "B"
of equal skill and willingness

Case I

1. Operator "A"
   60c per hr.
2. Machine "A"
   Can maintain arc 80% of time on production work.
3. 225 amperes at 50 volts available.
3a. Kilowatt rate 3c.
4. Bare wire 10c per lb.
   Machine "A" 3.4 lbs. per hr.
5. Same supervision in both cases.
   Production work.
6. Price, Machine "A," $1,500.

Case II

Operator "B"
85c per hr.
Machine "B"
Can maintain arc 50% of time on production work.
150 amperes at 20 volts available.
Kilowatt rate 3c.
Covered wire 18c per lb.
Machine "B" 2.6 lbs. per hr.
Price, Machine "B," $1,000.

Total Cost 10,000 Hours or Approximately 5 Years' Operation

Case I

Labor 0.60 × 10,000 ..... $ 6,000
Productive hours, .8 × 10,000 8,000

Power Cost

$$8{,}000 \times \frac{225 \times 25}{.50 \times 1{,}000} \times \$0.03 \quad \ldots\ldots \quad 2{,}700$$

Cost of Electrodes
8,000 × 3.4 × $0.10 2,720

Interest Charge for 5 Years
Machine "A" @ 8% 600
TOTAL $12,020

Case II

Labor $0.85 × 10,000 ..... $8,500
Productive hours, .5 × 10,000 5,000

Power Cost

$$5{,}000 \times \frac{150 \times 20}{.23 \times 1{,}000} \times \$0.03 \quad \ldots\ldots \quad 1{,}950$$

Cost of Electrodes
5,000 × 2.6 × $0.18 2,340

Interest Charge for 5 Years
Machine "B" @ 8% 400
TOTAL $13,190

Unit cost of doing work in Case I is $12,020 ÷ 8,000, or $1.50
Unit cost of doing work in Case II is $13,190 ÷ 5,000, or $2.64

The above figures do not show the total actual cost because no overhead expense is included. The effect of the variation of the variable factors, however, is shown.

Welding Compared with Riveting

The electric arc welded joint may be made stronger in tension, compression shear or torsion than is possible with riveted construction. Welding adds to the strength of the joint. Riveting, owing to the necessity of punching or drilling holes for rivets, can never give a joint as strong as the original section.

Figure 13 shows an automobile truck frame originally prepared for riveting with gusset plates welded. Stressed to failure the metal failed due to the rivet holes but did not fail in the weld. Welding in this case permits a stronger structure than is possible with riveting.

Owing to the newness of the welding processes, and the lack of experience among engineers with it, certain restrictions are placed on its use. These restrictions will be found in the section relating to the rules that govern the use of autogenous welding, as applied to pressure vessels, railroad construction and repair work, shipbuilding, etc.

The cost of straightaway welding is less than the cost of the same class of work riveted.

Miscellaneous

AMERICAN WELDING SOCIETY

Standardization Rules For Electric Arc Welding Apparatus

Purpose and Plan of Rules

The purpose of these rules is to provide standards for use in connection with specifications for, and the purchase, sale and use of, arc welding apparatus.

Classification

For the purposes of convenient designation arc welding apparatus shall be considered to be of three general classes:

(a) Generator or Motor Generator Class. This class includes, special generators driven by prime movers, special generators direct connected to electric motors, converters and dynamotors.

(b) **Transformer Class.** This class refers to special transformers connected to a source of alternating power, the secondary circuit of which supplies the arc or arcs.

(c) **Rheostat or Reactor Class.** This class includes the type of equipment which is connected directly to the source of supply, the voltage being reduced by means of a rheostat or reactor to the proper value for the arc or arcs.

Definitions

Arc e.m.f. is the total e.m.f between the electrode and base metal.

Arc stream e.m.f. is that portion of the arc e.m.f. that varies with the length of the arc.

Electrode e.m.f. is that portion of the arc e.m.f. that depends upon the character and condition of the electrode.

Open circuit e.m.f. of a welding circuit is the e.m.f. when no current is flowing.

Time of recovery is the time required to assume conditions to within 5 per cent of their final value in an automatically regulated welding circuit after a definitely specified disturbance has taken place. The time of recovery of a constant-current machine is measured as follows: Insert resistance in the welding circuit of such value that normal full-load terminal voltage of the machine is registered across it at full-load current; short-circuit one-half of the resistance and allow conditions to become stable; then instantly remove the short-circuit. The time required for the current to return to within 5 per cent of its original value is the time of recovery. The time of recovery of a constant-potential machine is measured as

follows: Insert resistance in the welding circuit of such value that full-load current is registered at normal full-load voltage; short-circuit one-half of the resistance and allow conditions to become stable; then instantly remove the short circuit. The time required for the voltage to return to within 5 per cent of its original value is the time of recovery.

Closed-Circuit Arc System is one in which the circuit is normally closed and the arcs extinguished by paralleling them with a low-resistance circuit.

Open Circuit Arc System is one in which the circuit is normally open and the arcs are extinguished by separating the electrodes.

Constant e.m.f. welding source is one that automatically maintains its e.m.f. within 5 per cent of the full-load setting over the range from full-load to no-load and has a time of recovery of not more than 0.3 second.

Constant Current welding source is one that automatically maintains its current constant within 5 per cent of its rated capacity over the range of welding voltage, allowing from 15 to 25 volts per arc, and has a time recovery of not more than 0.3 second.

Constant Power welding source is one which, when adjusted to give rated power output with an arc voltage of 20, will automatically maintain this power output within 5 per cent of the rated value, with variations in arc voltage of 10 per cent above or below 2 volts, and has a time of recovery of not more than 0.3 second.

Variable e.m.f. welding source is one in which the e.m.f. reduces as the current increases, but not in such a way as to qualify as a constant-energy source.

Selection of Arc Welding Apparatus.

The following information relative to the apparatus which it is proposed to supply and the conditions under which it is expected to use such apparatus is to be furnished by the prospective supplier of the apparatus and the prospective purchaser respectively.

(a) By Prospective Supplier

1. Rating of apparatus, the rating to be defined as in A. I. E. E. Rule 3508.
2. Number of arcs that can be operated at one time.
3. For A.C. power supply (regardless whether welding apparatus is A.C. or D.C.) maximum momentary kilovolt-ampere demand, power consumption and power factor at normal rating. For D.C. supply maximum momentary power consumption and power consumption at normal rating.
4. Efficiency as defined in A. I. E. E., Rule 3514, and measured in accordance with Rule 102, given below.
5. Weight, dimensions and portability.
6. Maximum voltage variation permissible at the power supply terminals without causing unsatisfactory operation either momentarily or continuously.
7. Method of regulating current and the number of steps available.
8. Current and voltage characteristics of the apparatus.
9. List of accessories and attachments.

(b) By Prospective Purchaser

1. Kind of electric power available, i.e., D.C. or A.C.
2. If supply is A.C., give frequency and number of phases.
3. Voltage of supply circuit.
4. Normal fluctuation of voltage (and frequency if A.C.) of supply circuit at the point where the proposed apparatus is to be connected.
5. Regulation of circuit at point at which proposed apparatus is to be connected that is the drop in voltage per 100 k.w. line load.
6. If no source of electrical power is available, give information in regard to the kind of mechanical power that is available for driving a special generator.
7. Apparatus to be portable or stationary.
8. Number of arcs required.
9. Supply of experienced welders.
10. General class of work to be welded.

Tests

Temperature Rise.—The temperature rise of any part of the apparatus after operating one hour at rated output shall not exceed the limits prescribed by the Standardization Rules of the A. I. E. E. for that class of apparatus when measured in accordance with those rules. The full rated output should be maintained continuously for one hour by means of a suitable resistance.

Efficiency.—(a) Input-Output Method. The efficiency shall be taken as the ratio of the power output to the power input after operating one hour continuously at the rated output with an ambient temperature not exceeding the limits prescribed by the A. I. E. E. for that class of insulation. Average of several readings taken at the end of the one-hour run shall be used. The power output shall be measured at the machine terminals to which the arc circuits are connected and the power input shall be measured at the machine terminals which are connected at the source of the supply.

(b) Conventional Efficiency. The conventional efficiency of an electric machine or apparatus is the ratio of the output to the sum of the output and the losses, or of the input minus the losses to the input, when, in either case conventional values are assigned to one or more of these losses. The conventional efficiency shall be measured as provided in the standardization rules of the A. I. E. E.

THE WELDING DEPARTMENT

Selection of Operators. Welding is a difficult art to master thoroughly. There are, to be sure, thousands of welders who are doing satisfactory work, but very few of them can be said to have thoroughly mastered their work. **Only steady and conscientious men will make good welders.** As far as previous training is concerned, some authorities claim that a background of practical experience in some mechanical trade is essential to rapid advancement.

Training of Operators. Whenever the subject of testing welds is discussed before engineering societies the point has always been made that the skill and disposition of the operator is one of the most important considerations. The test weld is of little value to the plant manager unless he knows that his operator is trained to make perfect welds under actual working conditions. Naturally it requires proper training to produce welders of this sort, and the question of providing this training has not usually received the attention it deserves. The method of training depends so much upon local conditions that no general course can be outlined, but a few general principles can be set down, which deserve the attention of all users of arc welding equipments.

One of the best ways to obtain welding instruction is through the schools maintained by manufacturers of welding machines.

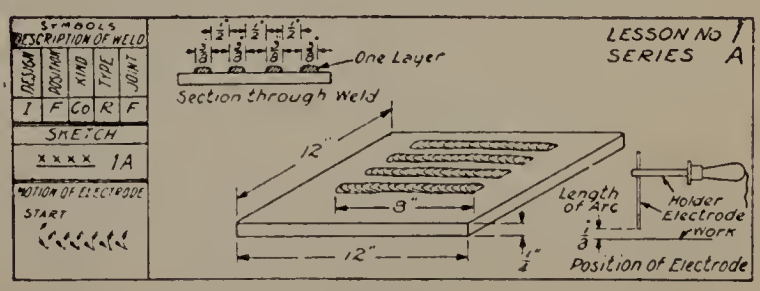


Fig. 1.

This instruction is handled by men who are thoroughly familiar with the construction and the operation of the machinery, and who know how to get from them the maximum efficiency consistent with sound welds. Their instruction is based on a desire to secure only the best grade of workmanship, and to have the students understand

thoroughly the prineiples of good welding practice. Every large welding department should include at least one man who has had the benefit of this fundamental training. It is not practieable nor necessary for all welders to be sent out after it.

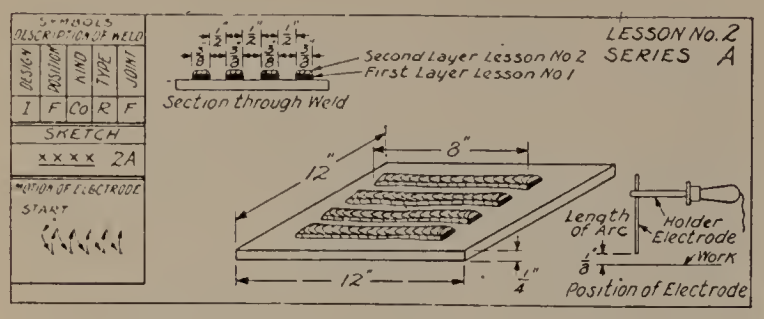


Fig. 2.

In the first plaee, eonsiderable care must be exereized in the selection of men to b trained. If possible, the candidate might well be required to spend some time working

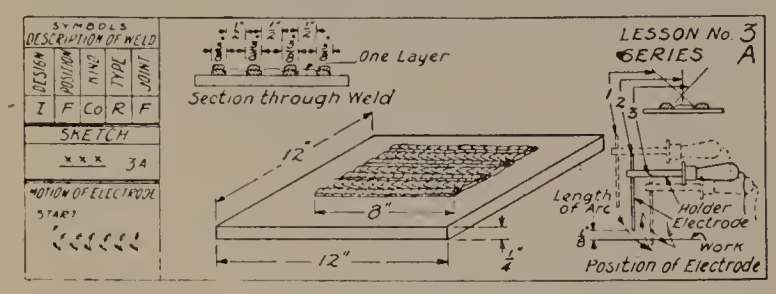


Fig. 3.

as "helper," long enough to become familiar with the procedure and to allow th supervisor to determine whether or not he is apt and conscientious. The second step should include praetical demonstrations of the process and an explanation of what takes plaee. This will often have to be repeated a few times, because careful questioning will show that the average workman cannot master all the essentials at a single lesson. In the long run however, it will be profitable to take the time to make the prospeetive welder know the work before putting him to work.

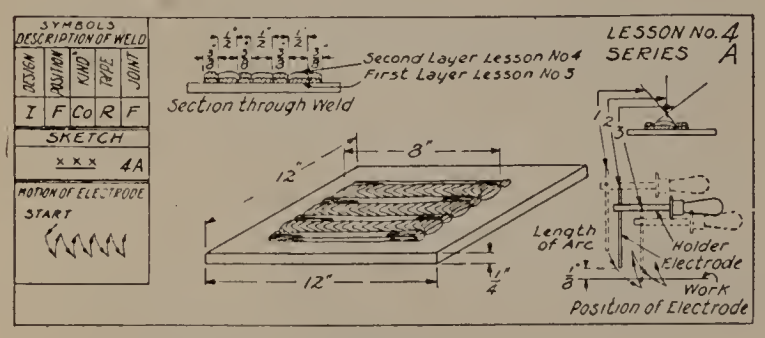


Fig. 4.

If the operator is being trained for production work, where all his welds will be made on the same metal and on the same design, it should be made clear to him that his work is highly speeialized and that any new class of work may, and probably will, require a ehange of proeedure. Then if he has been well trained in striking and holding the are, eontrolling the heat, and getting thorough fusion and penetration it will not be difficult for him to adapt himself to changing conditions with the aid of a little extra coaching and study of good text books.

More time is required to make a new welder effieient on repair work, where each new job presents a new problem and ealls for a new method of handling. A man with a meehanieal turn of mind will soon beeome profieient in repair welding, however, if he is carefully instrueted in the **reasons** for all changes of proeedure.

Many large industrial plants have developed systematic eourses of instruetion in manipulating the electrode, so that the welding foreman knows just what the operator has done when the instruetion work is finished. Figures 1 to 4 are four of the lessons used in training welders for the Emergeney Fleet Corporation. The first lesson eonsists in laying four parallel straight beads about eight inehes long on a steel plate. In the seeond lesson the student lays a seeond bead atop eaeh one made in the first. In the third lesson he deposits a bead in eaeh of the three grooves, and in the fourth he eompletely fills the grooves. At the end of the fourth lesson the work is inspected to make sure that the last welding material deposited is flush with the adjoining metal, and that all the metals are in perfeet unity. The sketches indicate the design of the weld, the motion of the eleetrode, the position of the electrode, the length of the arc, and the appearanee of the result. This is a typieal set of exercises for the beginner, and is ordinarily extended to a eomplete course of exercises to give the student eontrol over the width, depth, and direetion of the deposit using different sizes of wire and different amperage on the welder. The instruetor makes eareful inspeetions of every exereise and requires the student to repeat each one until he has become thoroughly grounded in the prineiples involved.

Every course of training should include instruetions in V-ing out the line of the weld so that thorough penetration will be assured, eleaning the surfaee of dirt, grease and scale to avoid impurities in the weld, studding for east iron welds, preheating or other preeautions for preventing distortions, and reinforeing.

Inspecting Arc Welds

The welding supervisor ean usually judge the skill of the welder by the uniformity of the are deposited metal, and the presenee of slag as indicated by the surface appearanee. A more careful inspeetion for possible brittleness of the deposit can be made by chipping it off with a cold chisel. Brittle welds will, of eourse, fail quiekly under transverse stresses. Porosity is another important defect that must be avoided, and can be detected by putting kerosene on one side of the weld. If the weld is porous, or contains similar defeets extending through the piece the oil will find its way through to the other side. More extensive methods of loeating defects will be found in the seetion on "Testing Welds." The visual tests outlined above are just complete enough to help determine whether the welder is faithfully observing the fundamental rules. His skill in holding the arc is indieated by the lengths of the deposits since the less skillful operator will break the are more often. The inspection of the under side of the weld will show whether he is getting enough fusion at the bottom of the weld.

Forging Arc Welds

Are deposited metal being known to lack some important eharacteristies of metal that has been subjected to heat treatments and mechanieal treatments, the question has often been raised as to how far the arc deposit ean be altered by mechanical treatment. O. H. Eseholz has made an extensive series of tests on the possibilities of forging are deposited steel, whieh have been reported in detail in **The Welding Engineer, the** conelusion from these experiments being summarized as follows:

Are Metal is forgable over the following approximate temperature range: 750°C (1.380°F) to 1,316°C (2,400°F).

Forging imparts a eonsistent high ultimate tensile strength, of the order of 58,000 pounds per square ineh, to low earbon deposits.

If the forging operation is eontinued to a red heat the elastic limit may be practieally doubled.

Forging increases the duetility of arc metal, the elongation exceeding 30 per cent **and the reduction in area exceeding 50 per** cent.

The fatigue resisting property of east low carbon arc deposited metal may be greatly improved by hammer forging.

This property is influenced by the forging temperature and degree of mechanical work done.

Hammer forged cast arc metal may be superior in fatigue resistance to mild carbon rolled plate.

Forging of low carbon arc deposited metal increases its elastic limit and yield point, as well as ultimate tensile strength.

The ductility of arc deposited metal may be greatly increased by forging.

If arc welded mild carbon open hearth steel is forged at the joint the joint will be stronger than the base metal.

Resistance to alternating stress is improved by forging, so that the fatigue resistance of the arc metal is comparable to that of the plate.

No inherent limitation to the development of the arc welded joints having greater strength, ducility or fatigue resistance than those found in this investigation have been encountered. While the strongest weld reported had an ultimate tensile strength of 132,445 pounds per square inch and the most ductile arc deposit a reduction in area of 60 per cent there was no indication that these values could not be exceeded with a further study of the effect of mechanical and heating treating processes.

It is possible to obtain alloy steel arc welds having physical properties comparable to those of the base metals.

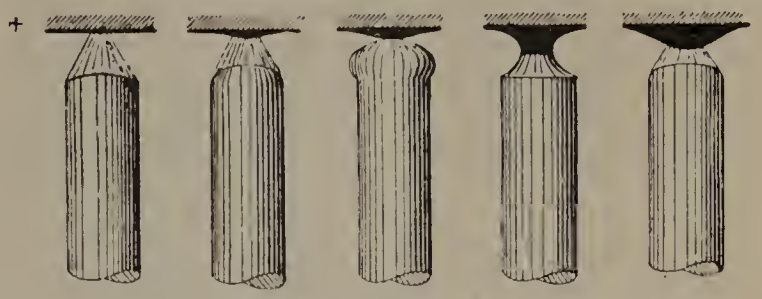
OVERHEAD WELDING

There are no insurmountable difficulties in the way of depositing metal in an upward direction, for great quantities of this work can be found daily in the boiler shops, railroad shops, shipyards and tank works. It does require a great deal of skill and care, however, to arrive at first class results. Mr. O. H. Escholz has advanced the theory that the transfer of metal in overhead arc welding is accomplished in different ways according to arc lengths; that an overhead deposit made while holding a long arc will be relatively small and due only to condensation of vaporized metal or pellet impact, while in the case of the short arc there is a globular growth until contact is made with the liquified plate or deposit surface, whereupon the forces of adhesion and surface tension at the plate overcome the combined forces of gravitation, cohesion and surface tension acting to hold the globule to the electrode surface.

The cycle of deposition in this latter case appears to be as follows:

1. Metal at each terminal is liquified upon striking an arc.
2. The molten electrode end assumes an approximately spherical form, due to the well known phenomena of surface tension causing a fluid material to contract into the smallest volume.
3. This globule enlarges with continued application of energy until with the aid of electrode manipulation its upper surface is brought into contact with the overhead pool, thereby short circuiting the arc stream and causing the lifting forces to act upon it.
4. Forces of surface tension and adhesion at the contact area between the overhead plate and the globule cause the globule to change its form and spread over the plate surface.
5. As the metal spreads, the area in contact with the plate increases and therefore the lifting forces are also increased, causing an acceleration in metal transfer. These forces act until the globule is lifted off the wire electrode end, when the short circuit is broken and the arc re-established.

It is evident that the forces which deposit the metal must overcome the forces of gravity, cohesion and surface tension at the end of the electrode. From further investigation of the factors affecting these forces it appears that they may be overcome by using a small diameter electrode and holding a very short arc. The composition of the electrode is known to have some influence on the ease of deposit, but it does not seem practicable to evaluate it until further research has been made. In line with this same theory it is suggested that heating the overhead joint locally helps to start layer deposition, since it facilitates the initial production on a cold plate of a "wetted" surface to which the globule must be attached by the forces of surface tensions and adhesion.



Illustrating the Theory of Overhead Arc Deposits

However, if the joint temperature is uniformly increased to a high value deposition will be retarded, since the rate of congealing of deposited metal is decreased.

Procedure in Overhead Welding*

The method described below is one which may be used in welding of cracks and seams in crown sheets or on any seam in a vertical plane. Any operator with a few weeks' experience with the process can do the work and the results will be uniformly satisfactory.

Welding overhead requires more current than welding in horizontal plane. Any welding machine should be set to give its maximum voltage for overhead welding, because the tendency for the arc to "hang on" is greatest when the voltage is highest. The most difficult part of the welding should be done with ⅛-inch electrode, using from 130 to 150 amperes. In working overhead with a rather heavy current the metal deposited may stay red hot for a few seconds. The operator should always wait until the last layer of the metal deposited has cooled to the point to where no color can be observed to avoid having the metal "run" badly. The work should be brushed thoroughly with a stiff wire brush between each layer.

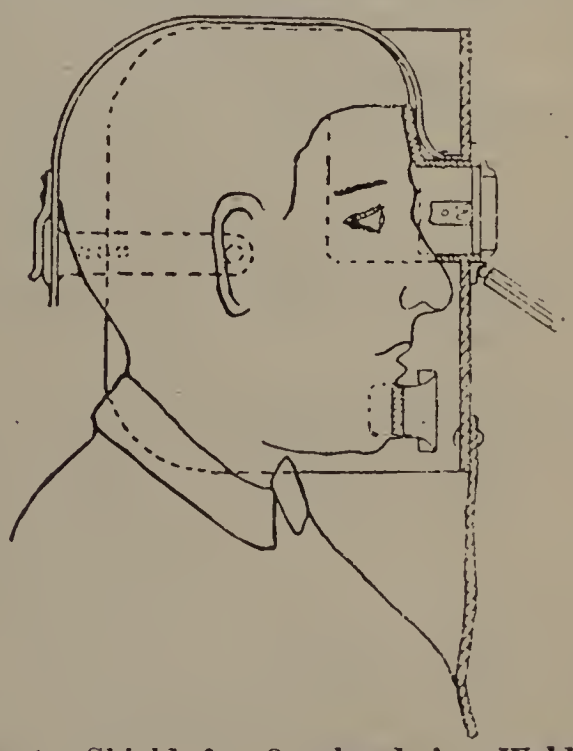


Fig. 1.—Shield for Overhead Arc Welding.

The operator must have a shield which is comfortable and which allows him to see a weld without straining his neck. Both hands must be free. One hand should be used to steady the other. The shield shown in Fig. 1 is one of the most satisfactory obtainable.

**Written for* THE WELDING ENGINEER *by R. E. Kinkead.*

Fig. 2 shows the easiest case of overhead welding. The weld should be started at the bottom and carried diagonally upward (see Fig. 3, side view). This may be carried the length of the seam, laying one bead of metal on and always following the pattern. The next layer can be started in the same manner at A, and carried to D. The important thing is to keep the diagonal pattern which makes the work easy to do.

Fig. 4 shows a typical overhead crack which has been properly V'd out. Welding the crack in this condition is very difficult and in most cases results in an unsatisfactory job. The job can be made easy by following this method: Cut a piece of ⅛-inch

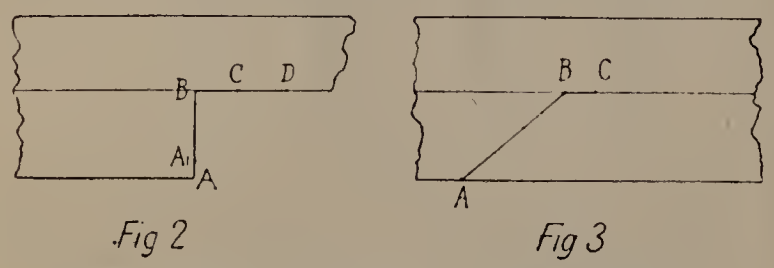


Fig 2 Fig 3

Figs. 2 and 3.—Simple Overhead Welds.

sheet about T ("T" equals thickness of plate) inches wide and of a length from 3 to 6 inches, depending on the length of the crack. If the crack is a very long one cut enough 6-inch pieces to go the length of the crack. Now stick a ⅛ or 3/32-inch electrode near the center of one of these pieces and very close to one end. This provides a handle. Poke the piece up through the crack and bring into position, shown in Fig. 5. Tack the ⅛-inch piece in two or more places, and weld acording to the pattern shown in Fig. 6. Allow metal to cool between each layer so that the color disappears. Brush between each layer. In actual boiler work it will usually be found that the ⅛-inch piece will not fit down tight over the crack due to the boiler scale. This will actually help the job rather than hinder it so long as the gap is not more than 5/32-inch. The section through the weld will look like Fig. 7. The excess metal beyond line A-A may be chipped off so that the weld is flush with the plate.

work and that it puts the reinforcing on the water side of the plate.

When building up on overhead work, remove the roughest part of the slag and foreign matter from the work with a bobbing tool or caulking tool. Follow up with a sand blast and finish with a wire brush. The cleaning operation is extremely important in

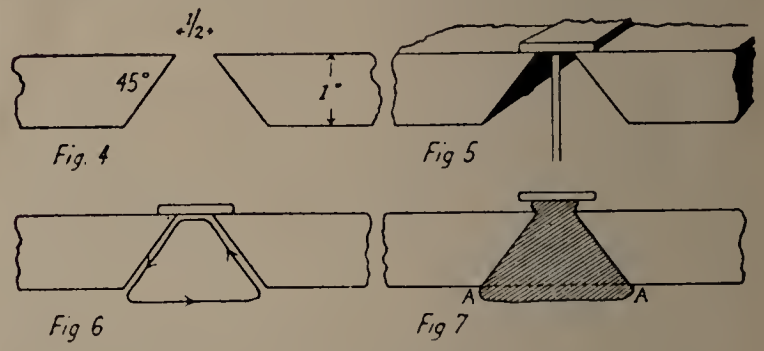


Fig. 4 Fig 5

Fig 6 Fig 7

Figs. 4 to 7.—Procedure in Overhead Arc Welding.

overhead welding, because the cleaner the plate or worn part the easier it will be to apply new metal.

The most essential characteristic of the arc welding machine for overhead work is that it should operate so as to deliver a constant even flow of current, and the welding wire used should be free flowing and uniform. Fast work should not be encouraged because the economical work is encouraged by slow and even, careful welding. A good operator cannot be expected to operate either one-fourth or one-half as fast on overhead work as he can on horizontal or vertical welding. Experienced overhead welders say that if the narrow part at the head of the V is filled up first, it will be found much easier to fill the wide part later. It is also recognized that a ⅛-in. reinforcement of the weld should be made whenever possible, because it is always difficult to get to the other side of the overhead V, and it is always best to play safe.

Holding the Arc

It requires a little practice to get the knack of holding the arc at exactly the right length to prevent the electrode from freez-

TROUBLES OF ARC-WELDING OUTFITS

SYMPTOM	PROBABLE TROUBLE	TEST
Current varies	Broken lead	Examine lead
	Poor ground connection	Examine ground
	Heavy intermittent load	Watch lights
Current seems too hot but penetration is poor	Reversed polarity	Use graphite electrode Use dish of salt water Use volt meter Use polarity indicat...
Current dies down		
1. Speed of M-G. set falls off	Supply line too small	Examine
	Poor contact in motor circuit	Feel for hot spots
	Fuse blown (3-phase motor)	Motor growls
	Motor commutator dirty	Examine
2. Speed of M-G. set holds up	Generator commutator dirty	Examine
	Loose field connection	Examine
Arc hard to start and hard to hold	Seperately excited field not working	Open circuit voltage low
	Field adjustment out of balance	Inspect setting of rheostats

Arc Welding Troubles and How to Locate Them

The same plan may be followed on seams in a vertical plane. The great advantages of the practice are that any operator can do the ing to the wood. This is accomplished by feeding the electrode downward at a uniform rate and advancing the arc continually

so that a uniform deposit of metal will be secured. Good results are made possible by always keeping the arc at the advancing edge of the the crater. The operator will soon become accustomed to using a slow rocking motion when he accidentally brings the electrode too close to the work so that it freezes, and will find that it is not difficult to disconnect the electrode without breaking the arc.

FINDING THE CAUSES OF ARC WELDING TROUBLES

Arc welding equipment, like any other electric machinery, should always be under the care of someone who knows what he is doing. Elaborate repairs and adjustments should not be undertaken except by expert electricians. There are, however, a few simple cases of trouble which may be located by the operator. For example, if the current shows a tendency to vary widely while welding is going on, the trouble may be due to a broken lead, poor ground connections, or a heavy intermittent load. This can be found by examining the lead and ground connection and by putting an electric light in the power circuit which will indicate an intermittent load by burning first brightly and then dimly.

If the current dies down, and the speed of the motor generator falls off at the same time, the first thing to examine is the supply line which may be too small. It may also be caused by poor contact in the motor circuit. To check up on this point, feel the motor carefully for hot spots. If it is a three phase motor which is acting in this manner, listen for a growling sound which will indicate that the fuse has been blown, then examine the motor commutator as the trouble may be due to a dirty condition here. In case the current dies down while the speed of the motor generator holds up, examine for a dirty generator commutator, and for loose field connections.

If the current seems too hot, but the penetration is poor, the trouble may be due to use of the wrong welding wire, or it may be that the metal worked on is not suitable for welding. Sometimes this trouble is caused by reversed polarity. If this trouble is suspected, a test should be made with a dish of water or a polarity indicator. If these instruments are not available substitute a small piece of graphite electrode for the metallic electrode and strike an arc. If the polarity is correct, the arc will be fairly easy to start, and a crater will start in a few seconds, but if it has been reversed the arc will be harder to start and will be unsteady, no crater will be formed on the work, and the pointed end will disappear from the elctrode. If the arc is hard to start and hard to hold, it may be due to the separately excited field not working properly on account of poor contact, sparking brushes or dirty commutators. This will be indicated by a low open circuit voltage. The trouble also may be due to the poor adjustment of the field, and the rheostat setting should be inspected.

In all cases where the tests indicated above do not locate the difficulty and correct it, the services of an expert electrician should be secured.

STUDDING*

Assuming that steel can be welded to cast iron where the parts are free to align themselves, which assumption is a fact, the use of studding comes in where the weld is in such a position that the parts are not free to align themselves to the contracting strains which result during cooling. In the latter case, a steel weld made to cast iron without studs looks fine until just about the time it is being most admired during cooling, when it invariably cracks along the edge of the weld. This is easily explained when we consider that steel has approximately four times the strength of cast iron. The definite location of the break comes about because the cast iron next to the weld has become chilled cast iron, no matter whether it was originally so or not, and a sharp demarcation of structure together with a possible layer of weaker cast iron causes the break invariably to take place in this layer of cementite.

If, however, steel studs are properly distributed along the face of the cast iron to be welded or adjacent to the joint, so that the weld cannot pull away from the cast iron, the cooling strains result in stretching the steel weld, and the union between the weld and the cast iron and steel studs is maintained as it was made.

Remembering that steel has four times the strength of cast iron, **the problem is to so proportion the studs that the ratio of the cross section of the steel to the cross section of the remaining cast iron is something less than four to one at any one section that will be subjected to cooling strains at one time.** This, in general, is a very simple and easily applied method and means, in general large studs for large sections and smaller studs for smaller sections. Common sense together with welding experience is required in placing the studs. The writer has seen this studding method abused horribly by people who evidently did not understand why they were using this method; and there is no doubt that some of the unsuccessful work done by amateurs is partly due to the prevailing opinion that the studs are simply there to functions as tent stakes. That this is not true, can also be seen from the fact that the steam tight joints on cast iron can be made by this method, showing that the weld to the cast iron has been maintained in full efficiency by the use of the studs.

Another very useful application of studding is the use of large studs as an anchor or neucleus for breaks in castings such as gear teeth. One to three of these large anchor studs, together with some smaller regular studs appropriately distributed will provide the necessary weld strength to the cast iron as well as strength to withstand some shear and thrust strains. The weld, built up to size and machined off, furnishes a perfect wearing or bearing surface. This latter method of studding is also applicable to cast steel, where the original section has not been adequate to withstand the strain.

Details of how to accomplish this studding are:

First: Vee out the crack on both sides of the break from one surface, if only one is accessible, or half way from both surfaces if both are accessible for welding; saving enough parts of the original break to keep the piece securely clamped in alignment. Before any of the welding is done, the the stud holes are to be drilled and tapped with a **bottoming** tap, and the studs screwed in tight, completely filling the hole for a distance of at least **four times the diameter of the studs.** A convenient way of doing this is to have rods threaded for their entire length, screw these in tight, and saw off ¼-inch to ⅜-inch above the surface of the work depending on the accessibility. That is to say, **a narrow vee should have the studs closer to the work than a more open one.**

Second: In welding the following procedure **should be carefully adhered to. Weld** around the studs so that they are part of the cast iron: then weld between the studs crosswise or diagonally until the entire surface of the cast iron that has been veed out and the adjacent surface forming the underside of the pad is completely covered before proceeding with the main filling in. That is to say, **add metal, one bead at a time so that no great section of the weld congeals from the molten state at any one time.**

First welding the stud to the cast iron makes the stud an integral part of the casting. Welding from stud to stud diagonally or crosswise draws the fractured surfaces

**Extract from a paper written by C. J. Holslag for the American Welding Society.*

together to their original contact, if a small amount of the original break has been left intact at the bottom of the vee. This can be done in most instances; but, naturally, not if pieces are broken out and lost, and must be replaced by a casting or forging. In this steel studding process for cast iron, especially on cylinders and the like, machining is often necessary subsequent to welding, and the hard stratum of metal directly under the weld prevents ordinary cutting operations and grinding must be resorted to. There are other means of taking care of this hardened layer for machining on the surface, one of the newest of which is to finish the machined part with a nickel-copper electrode, which electrode has the property of so merging the cast iron that there is no hard layer of cementite formed. This electrode was developed by the automobile trade for repairing scored cylinders and the like. Older methods are to calk the bottom of the vee, say with copper, which is machined off later. Probably the best method of all is to supply a bushing for the finished part. Many cylinders, especially those of steam engines, are built with this bushing originally; and, in welding, the bushing is to be removed and perhaps slightly refitted after the welding job is finished.

In welding cast iron with the metallic arc, using steel filler material, the difference in contraction between the molten added layer and the casting often causes trouble. The strength of the added steel is much greater than the strength of the cast iron, so that the steel, upon contraction, may pull away from the cast iron (Fig 2), or in come cases. where good fusion of metals has been secured, the cast iron will be fractured. The fact that the separation usually takes place at the line of slag or the point of contact of the two metals is due to poor fusion of metals and to the fact that this is the line of creepage or movement between the metals. Even though good fusion of metals has been obtained, the separation will be in the vicinity of this line and on the cast iron side.

ARC WELDING OF CAST IRON*

The steel metallic process of welding is the only method adaptable for certain applications. Examples of this are found frequently in castings which permit the use of only a limited amount of heat, and in jobs which require welding to be done by overhead manipulation of the arc. This latter is usally prohibitive in other methods on account of the fluidity of molten cast iron.

The following outline covers the general procedure recommended for doing metallic arc welding on cast iron parts.

In preparing a casting for this process care should be taken to remove all scale and sand by chipping or sand blasting the entire surface to which metal will be fused.

A square groove is chipped along the line of the break or crack. The size of this groove depends upon the thickness of the casting and is usually ¼ in., ⅜in. or ½ in. square.

The groove is then filled up by welding until it is flush with the face of the casting.

Locate and set the first stud in the casting as close to the crack as practicable. The location of the stud is determined by the thickness and shape of the casting and the size of the stud. The size and number of studs is dependent upon the volume of added metal required to give the necessary strength. Studs should be long enough to extend through the first layer so that good fusion can be obtained between them and the second layer. The studs should be set as close to the edge of the break and to each other as practicable.

Weld around the first stud with a sufficient number of rows of deposit to reach the center of the break, as shown at X in Fig. 1. This procedure will determine the area covered by the metal surrounding one stud and will aid in locating the remaining studs.

Locate and set the necessary number of studs to complete the job. Chip or grind grooves, as shown in Fig. 1. These grooves may be either square or semi-circular, although ¼ in. square grooves are used most frequently. Grooves should be placed between the rows of studs if more than one row is used, and at the outside edge of the weld area.

Figure 1. illustrates the preparation as to grooving and studding, as well as the welding procedure to be followed.

Weld the grooves up flush with the face of the casting.

Weld the first layer around all studs as was done with the first stud. The outside

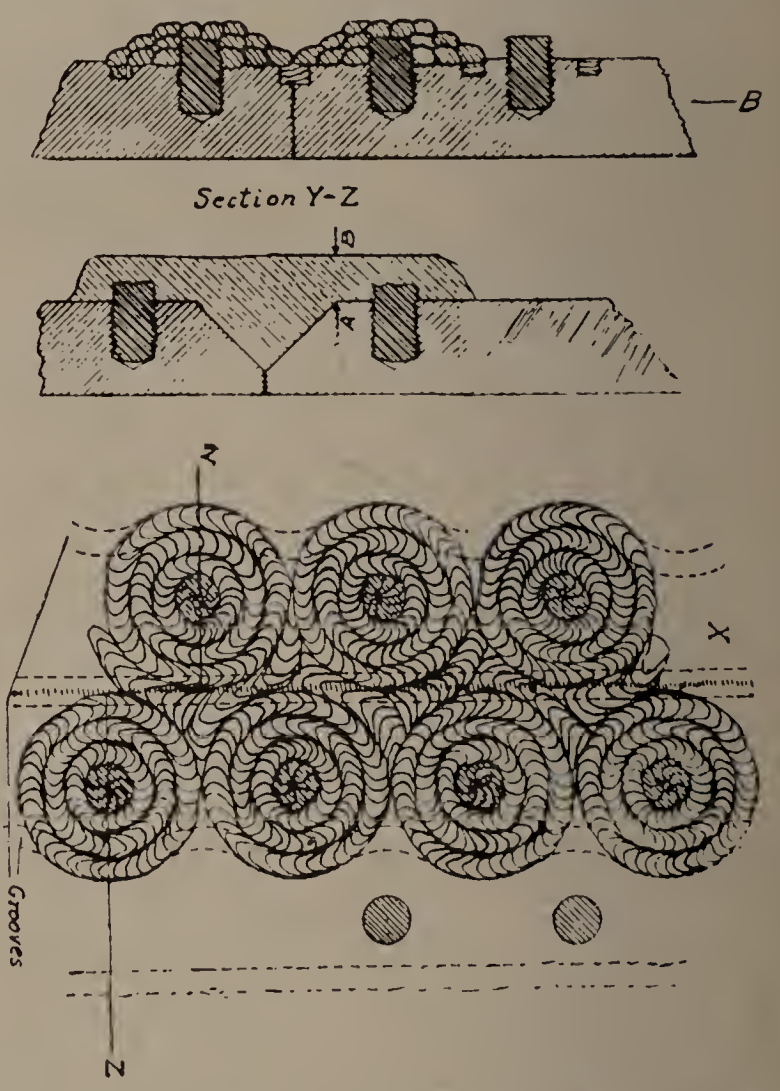


Fig. 1.—Preparing the Work, Studding, Grooving and Filling Procedure.

row of the pads of adjacent studs are not united at this time except where they emerge into each other at the outer circumference.

Weld the second layer around all studs (Fig. 1-B), taking care to make the pads cone shape, so as to leave a "V" to be filled when the pads are united.

Weld additional layers if required.

Unite all pads except at the line of the break, taking care to leave this operation until the last in order that the greater part of the shrinkage will have occurred before this union is made. In uniting the pads, when more than one layer of deposited metal has been added, it is best to follow the contour of the pads with additional rows of metal as the welding advances from the bottom of the "V" or base of the cones.

Unite the weld at the break, as shown in Fig. 1.

The operation of welding cast iron by the steel metallic arc method should proceed very slowly, with each addition of metal being very small in order that the heat absorbed by the work may be kept to a minimum.

Drilling at the end of the break or crack is optional and not often required, as the casting should never get warm enough to expand and extend the break.

*From a paper read before the American Arc Welding Society, by A. R. Allard.

One of the mistakes made in the application of this method of welding is the practice of building up heavy sections or layers of steel adjacent to the cast iron. When good fusion is obtained the section of steel can be easily kept at one-half that of the cast iron section required to give the necessary strength. It is evident that when the stresses are great enough to warp the steel, it will, in most cases, pull from, warp or break the casting (Fig. 2).

The square groove at the break, when filled by welding, closes up the break and offers a projection against which the shrinkage of the added material draws the adjacent sides of the casting, thereby utilizing as an

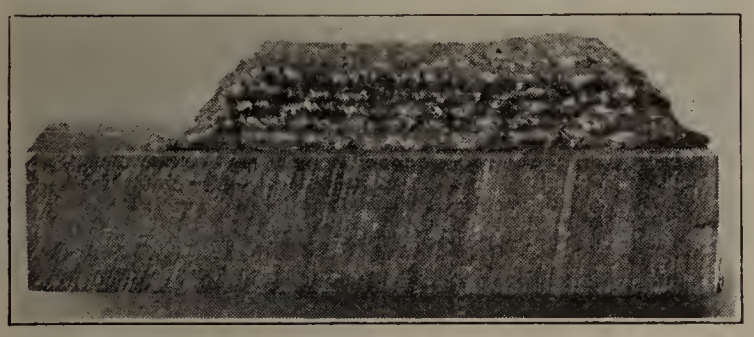


Fig. 2.—Steel Deposit on Cast Iron. Note How Deposit Pulls Away from Casting.

advantage one of the greatest trouble-giving factors encountered in the cast iron welding.

The other grooves are additional insurance against leakage when welding cylinders or containers for liquids or vapors. They also give additional strength to the welding.

The method of "V'ing" out the casting, as shown at "A" (Fig. 1), was inherited from the practice followed in gas welding and may be followed when welding sections of casting in which the carbon is found to be in a condition which will give good fusion between the casting and the added metal.

The heavy sections of graphitic cast iron usually encountered should not be "V ed' out, because the surface of the casting, which chills quickly when cast, affords a better quality of metal upon which to weld than is presented as the casting is cut below the surface. As the cut becomes deeper the amount of graphite present in the metal increases. Examination of "A," Fig. 1, Section A-B, will show that no increase o strength is gained by "V'ing" out in cases where the fusion between the metals is poor.

Figure 1-A also shows another disadvantage to the beveling method of preparation There is without question considerable shrinkage of the steel filler material no matter how carefully the work is done. Reference to the sketch will show that the shrinkage draws the bevels of the casting against the beveled boss of the added section, with the result that the pressure exerted tends to lift the steel section from the casting, and this, in fact, takes place in many cases.

The practice, as outlined, will keep the effect of shrinkage strains to a minimum by affording a procedure which will keep the work cool, and by affording means of equalizing, balancing and taking advantage of the stresses which cannot be eliminated. The use of small wire, as low current as permissible and straight line welding without weaving or oscillating of the steel electrode will also assist in keeping the work cool and minimizing the stresses.

The procedure most widely understood has been outlined. The ideal procedure would result in welds which would have the following characteristics:

(1) Good amalgamation of metals.

(2) Prevention of chilled metal at the line of fusion or in the weld.

(3) Provision for accommodating expansion in the casting.

(4) Elimination of gas pockets and holes

(5) Same coefficient of expansion between the casting and the added material.

(6) Deposition of added material which will approximate the characteristics of the original casting.

Each of the above characteristics can be obtained as follows:

(1) Good amalgamation of metals can be obtained by proper filler material and preheating.

(2) Chilled metal at the line of fusion or in the weld can be prevented by proper filler material and by preheating.

(3) Preheating will also accommodate expansion in the casting.

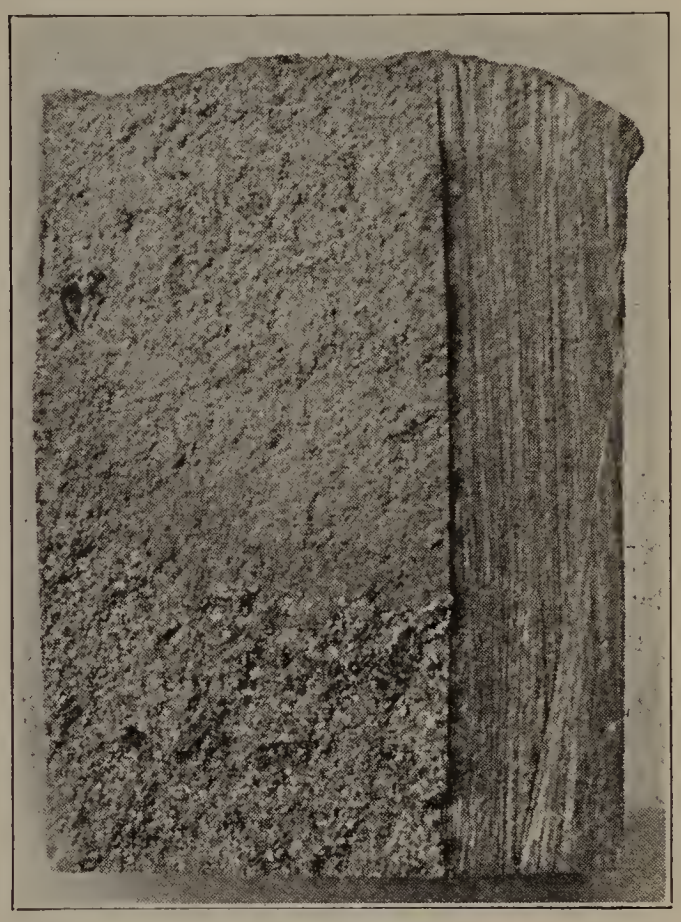


Fig. 3.—Cast Iron Sections.

Preheated to 1500° F and built by the Metallic Arc Process of Welding, using a Cast Electrode. The section was cut with a hack-saw to show that it could be easily machined, and was then broken to show the characteristics of the weld and original metal. Note the dense fine grain structure of the added metal and the graphitic structure of the original casting. The added material is stronger than the original casting and is easily machined.

(4) Proper filler material and preheating will eliminate gas pockets and holes

The proper filler material will result in a deposit which will have the same coefficient of expansion as the casting.

The proper filler material can be obtained which will approximate the characteristics of the original casting.

Although proper filler material and preheating will theoretically give an ideal weld, proper manipulation of the process and a clear understanding of the principles involved are necessary in their practical application.

Electrode Material

In good welding practice it is the usual procedure to use filler material having the same characteristics and which will respond to the same treatment, in the same way, as the material of the part being welded. It is also necessary that the expansion and contraction of the parent and added material be the same, and that an amalgamation of metals be secured. It is a logical procedure, then, to use filler materials of the same composition as that of the casting or part being welded. There is usually an allowance made in the filler material to take care of losses of the constituents which may be diminished by the welding process.

Electrode material for welding cast iron by the arc process, if governed by the above findings, would consist of cast iron with the following characteristics:

High carbon content to compensate for the loss of carbon due to the application of the intense heat of the arc and to promote the formation of good cast iron.

High silicon content to compensate for losses and to promote the formation of graphitic or free carbon cast iron.

Low manganese content because of the detrimental effects.

Low manganese content because of the retarding effect it exercises over the formation of free carbon or graphitic cast iron.

Low phosphorus content on account of the formation of very brittle iron where any appreciable amount is used.

Various compositions of cast iron electrodes have been tried in conjunction with preheating. The standard filler rods made for gas welding give very good results when coated with lime wash, and when the casting can be welded and heated to about 1500 deg. Fahr.

Preheating is necessary in connection with arc welding of cast iron if a weld having the ideal characteristics is to be secured. It accomplishes results as follows:

(1) It relieves residual strains and accommodates expansion and contraction in the casting and between the original and added metal.

(2) It eliminates gas pockets and holes, caused by reasons previously stated, by holding the metal in a plastic or fluid state long enough to enable the gas to escape and oxide or dirt to be released and floated to the surface.

(3) It aids in securing a good amalgamation of metals, particularly when welding graphitic cast iron, by reason of the extension of the period of fluidity which allows the slag to float free, and by reason of shortening the period of time required for the dissolving of the carbon, due to the fact that the preheating has already advanced the process. When castings are preheated the formation of the line of slag is reduced to a minimum.

(4) It permits cooling the metal of both the casting and welded sections as slowly as possible and thus prevents chilling and the attendant formation of chilled iron. Undisturbed cooling promotes the formation of free carbon which is necessary to the production of soft iron. It has been determined that if the cast iron is solidified quickly and then cooled very slowly the carbon, which is in the combined form at the time of setting, will change to the free form as

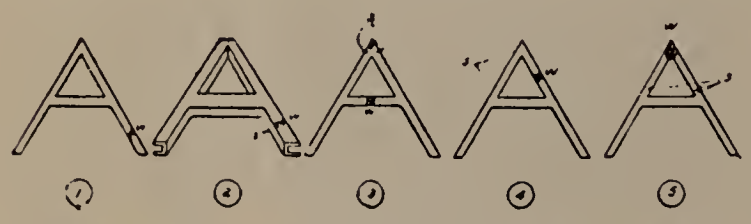


Fig. 4.—Stresses Set Up During Welding.

cooling progresses, thus producing a fine-grained iron of first quality. There is an opportunity in arc welding to duplicate this procedure by preheating the casting to the required temperature before casting or welding the filler material into the original metal, thus delaying the chilling and assisting in cooling the metal slowly. The change from combined to free carbon takes place very rapidly (Fig. 3).

Referring to the first point above, preheating to relieve residual strains and accommodating expansion and contraction will be clearly understood if the following points are kept in mind. When a section of metal is heated or cooled the expansion or contraction which takes place will produce stresses. This may be visualized by comparing the effect to the effect produced by driving a wedge between the sections at the point of heat application. The greatest stress is exerted at a time when the metal is just below the point of fusion, or at the time contraction has taken place. The effect of these stresses in welding practice will be understood by referring to Fig. 4. Assume that item 1 is to be welded at the point marked "W" and that the casting section at the point of welding is 5x1 in. An application of welding heat at the point "W" continues to expand the metal at this point until a point just below the fusion is reached. This expansion causes the free end to move outward in order to accommodate the greater bulk of material at the weld, just as if a wedge were being driven into the metal. After the metal solidifies, this greater bulk begins to recede or contract and continues to do so until a point is reached at which the casting assumes atmospheric temperature. With this contraction there is a corresponding movement of the free end of the casting. If, instead of the casting having the flat section shown in 1, it takes the form of that shown in item 2, where the leg section is similar to three sides of the square, the leg, instead of being free to move, is held more rigidly, causing considerable strain upon the lower side of the section and opposite the weld.

Upon cooling, contraction takes place as in the previous example, causing a severe strain in the lower section. If the casting is solid and the section so heavy that the welding heat does not penetrate all the way through, there is the same expansion and contraction, with their accompanying stresses and strains which often result in warpage and breakage.

Items 3, 4 and 5 show similar examples, the points "W" representing the places of welding and the points "S" where the greatest strain is exerted. Breakage from expansion and contraction stresses does not always occur at the point of greatest stress application, but at a point where the strength of the section is less than that required to withstand the stress applied at that point. An example of this is shown in item 3, where the weld is made in the cross member between the legs, and the strain being distributed about the apex of the angle formed at the junction of the legs. If the section of the apex is heavy enough to withstand the energy exerted, the breakage, if any, would then take place in the leg sections, and at a point which is less able to withstand the applied stress at that particular point. A close study of each particular casting with reference to its construction is necessary if proper care and precautions are to be taken.

If the casting is of simple construction it is usually only necessary to preheat it at the points of stress application, as outlined in the previous examples. If the castings are complicated in construction, the problem becomes greater as the intricacy and complexity of the casting increases, in which case it is usually necessary to preheat the casting all over in order to compensate for the liberation of residual stresses, expansion and contraction. In addition to preheating, it is often necessary to after-heat the casting, following the welding operation, if successful work is to be done. Many welders believe they are getting away with something when they weld a casting without preheating, and, though the casting may not crack at the time of welding, it may possess residual stresses which will send it back to the welding table like the proverbial cat.

The only objections to preheating are time required, probable warpage, cost and the heat to which the operator is exposed while welding. The latter consideration most often carries the situation when it should be secondary to all others, as it is possible to protect him from the heat if proper precautions are taken and suitable equipment used.

The development of arc welding of cast iron will probably depend upon the development and use of methods and applications of preheating, and the development of an electrode for metallic arc welding on cold castings which will deposit a ductile metal having a minimum coefficient of expansion.

Satisfactory results can be obtained by the steel metallic arc method and by the carbon arc method, using either cast iron or steel filler rods, if the work is preheated. When using steel filler with either method we have to contend with an area of high carbon steel which does not machine readily, even when in the annealed state.

Care must be exercised in the manipulation of the pencil with the carbon arc method, as at each spot where the carbon comes into contact with the surface of the casting a hard spot usually results.

In some cases of welding, when steel filler material is used, very good results have been obtained by annealing in addition to preheating. After-heating results in relieving strains caused by welding and in annealing hardened sections of the deposited metal.

One advantage of the preheating method is that the welding operation may proceed as rapidly as it is possible to push it, while welding done by the metallic arc method on cold castings is exasperatingly slow and tedious, since it is only practicable to add the metal a little at a time in order to keep the heat and attendant shrinkage at a minimum.

It is claimed that metallic electrodes of various compositions will produce a soft weld. The truth is that the added material may remain soft, but there will always exist an area of chilled cast iron on the cast iron side of the weld if the materials have been fused. Cutting with a hacksaw through the weld section will reveal the hard area, if one exists.

ELECTRIC ARC CUTTING

Although it is the common practice to use gas for cutting, yet there are many places where the electric arc can be used advantageously for cutting. In his handbook on arc welding and cutting C. J. Holslag gives the following instructions for cutting with the arc.

One of the most outstanding examples where a saving would result is that of rivet cutting. Here an outlay of ten or fifteen cents an hour for power and practically no other cost except one man's labor will cut from 100 to 200 rivets per hour at a cost of from ½c to 1c each; a good average being ¾c per rivet.

The arc will also cut the scrap section of a car, boiler or tank into charging size and will eat through sills, channels, or other stiffening members at a rate depending on the thickness, but at the same low cost of power. The arc will cut any metal ferrous or non-ferrous and including cast iron.

The thickness that can be economically eaten through by the arc lies below 4 and 6 inches for straight arc cutting. There is a method of nicking or breaking, however, where electric cutting is efficient for any size.

Other uses of the arc for cutting are cobbles, hot or cold, mold fringe and over-flow of ingot molds and miscellaneous cutting and nicking of scrap ends, and mistakes in rolling, etc. One great attribute of arc cutting is that the arc will cut cast iron, brass, aluminum, in fact all metals.

A wonderful field not yet fully developed, but being worked on industriously, is the substitution of the arc for hand chipping of seams in billets, especially those of complex alloy steels.

The current values necessary for these cutting operations run from 280 to 320 amperes for nicking or seaming with a special electrode, giving off oxygen at the heat of the arc to 450 to 550 amperes for graphite arc nicking, 600 amperes for rivet cutting and 800 to 1,200 amperes for general and heavy cutting. The voltage of the cutting arc runs between 27 and 45, a good average being 37. An interesting feature about variations of current and voltage is that **the maximum heat occurs with an arc length just longer than a "sputtering" arc.** This fact combined with the fact that the radiation loss is greater with the longer arc, makes it apparent to the operator that as far as maximum speed is concerned, **the best arc is a reasonably long one or a reasonably short one, whichever is perferred.** The chief point is to have the liberation of energy near the work to be cut up and not to waste it in heating up the atmosphere.

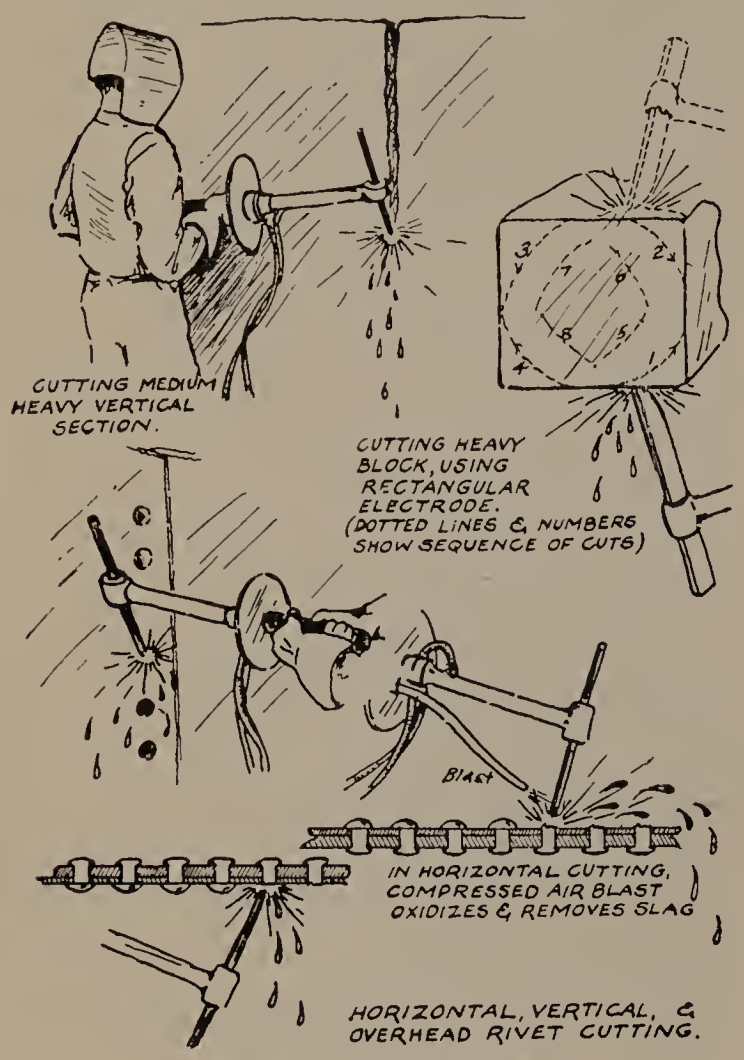
It has been found by extensive experience that the maximum wattage and hence maximum heat occurs in cutting as well as welding at the shortest arc which is not sputtery. This can also be seen by the fact that with a long arc the heat goes more to heat up the atmosphere than to melt away the metal. This proper arc length determines the voltage of the arc. The only other way, therefore, of increasing the heat is by increasing the current. Judgment must here be used, however. Increase of current means larger electrodes and hence more metal to be cut out, which loss of metal sometimes defeats the speed gained from the increase of heat, and a compromise must be effected. The latest development for this work is a low resistance graphite and the size popular for various current densities are about as follows: 200 amperes, ¼ to ⅜-inch electrodes; 300 to 400 amperes, ⅜ to ½-inch electrodes; 400 to 600 amperes, ½ to ⅝-inch electrodes; 600 to 800 amperes, ⅝ to ¾-inch electrodes; 800 to 1,200 amperes, ⅝ to 1-inch electrodes with probably ⅞ at 1,000 amperes.

For rivet cutting, due to its more intermittent character, the minimum size electrodes can be used. For instance ½ to ⅝-inch electrodes for 600 amperes can be used.

A very simple arrangement and a great help is to have a 12-inch electrode placed in the jaws so about 3 inches protrude from one end and 8 inches from the other, and use the short end and as it points and burns off keep pushing the cool and unused end through the jaw. Another way to keep the ends cool is to grab the electrode in the middle and use it from either end alternately allowing the other end to cool. It is useless to have any more of the electrode than is absolutely needed to reach the work being heated white hot by the current passing through it as this heat in the electrode is wasted and causes harm by burning up the cutting rod by oxidation. It will soon be noted by the operator that the used end points itself admirably for cutting, even if there is no point made to start. Complete explanation of this phenomenon is hard to provide but the fact remains that it so acts. In cutting rivets a slight rotary motion with a wrist fling when the head becomes molten seems to be the most sucessful manner to accomplish production. In cutting rivets only the first one must be reached for blind. As soon as the rod becomes white hot there is enough illumination to see through the mask to locate subsequent consecutive rivets, and if it is undesirable to touch the sheet to locate the first rivet, if the sheet is to be used over again, the rod end can be made white hot by an arc from some adjacent heavy part of a deliberately provided piece of scrap metal for that purpose. In cutting rivets where the sheet is to be used over again naturally the arc should not be drawn from the sheet itself and the operator will note that this is easily accomplished, the paint or rust on the sheet preventing the arc from ever jumping from the rivets to it unless it is deliberately coaxed over to the sheet by mislocation of the electrode. Of course the rivet head is generally painted and rusted or both but here a scratch at the end of the rod will start things going.

and if such contact is made the arc will not burn the sheet.

Cutting on heavy sections especially is generally best accomplished from the underneath side or from a vertical face tipped slightly greater than 90 degrees so that the molten metal can flow away, although the action is not entirely simply melting metal but oxidizing from the ozone of the arc which free oxygen assists in cutting, yet the molten metal must be allowed a sluice-way to pass through or it will solidify, and it is harder to cut through this slag metal than through original good metal. The piece can be stood up or tipped to the proper angle or a start for the cutting can be chosen so that the sluice-way is always kept open. In the cutting of cast iron especially this is easily accomplished. In cutting with the electric arc a reasonably smooth surface can be made by paying attention to one side only, or the cutting may be made rough and trimmed up reasonably smooth by a second application of the arc.



Electric Arc Cutting.

There has been developed recently a special electrode for cutting by the electric arc and for such purposes as piercing holes. This special electrode covered with a coating giving off free oxygen under temperature of the arc gasifies the entire steel melted, so that the boring action is uninterrupted after once started. This electrode is used by starting the arc and immediately pushing the electrode into the puddle with a mild pressure such as by the weight of the hand. After the hole is through the piece it can be widened to any size or shape desired by drawing the arc around its edges. Cutting can be done with this electrode in the same manner as hole boring by proceeding in a line or following the design desired. This type of cutting only takes between 250 and 350 amperes, and hence is especially useful in connection with welding. Where there is a combination cutting and welding machine supplied, i. e., one that will give up 200 or 350 amperes for instance, heavy sections can be welded top and bottom at a point approximately the center of a desired "V" or "X" to be cut out; then the "V" or "X" can be cut out by the electric arc, using this special electrode and keeping clear of the welding points so that the piece is held in its original alignment. Another method is to temporarily weld one side of a job then cut out the other side by the electric arc, weld that side permanently, then cut out the other side in the temporary weld and weld it permanently.

Refer to the illustrations. Where the piece is not too thick the cut can be made from the top down or horizontally from either edge. The cutting is done by moving the electrode across the thickness of the work with a slow movement downwards, flowing the melted puddle out of the trough and with a quick movement backwards, starting down rapidly so as not to allow the metal to cool off. With this method the piece must not be so thick but that it can be kept flowing.

Where the piece is so thick that this method cannot be followed, successive "bites" must be taken off the corners until the piece becomes thin enough to eat clear through. For instance, refer to the right hand illustration. If a good "bite" is taken off in the sequence shown, a free trough will always be kept clear for the molten metal to flow away.

A great aid to cutting is the use of a rectangular electrode which has the carrying capacity of a great deal larger round electrode and greatly reduces the width of cut and hence the amount of metal to be removed per cut. An electrode either round or square which contains a cored center of oxidizing chemicals greatly assists the cutting operation in making the metal more fluid and in burning some of the metal up as a gas. These cored cutting electrodes are being brought out in rectangular shape as well as round.

One of the most outstanding examples where arc cutting is economical is the cutting of rivet heads for the replacement of sheets or angles in cars, boilers, ship bottoms, etc. Here an outlay of 10 to 15 cents per hour will result with just one man's labor in between 100 and 200 rivet heads being cut off. The process as shown by the illustration is very simple: The arc is drawn from the rivet head and because the sheet is generally painted or rusted or both, the arc has no tendency to draw to the sheet and the head can be completely cut off, even below the sheet level, without the sheet being damaged. When cutting from the vertical or under side, the rivet head melted by the arc flows naturally away, but when cutting on the top horizontally, the molten metal must be pushed aside before solidifying. This is easily and cheaply accomplished with a compressed air jet operated by a trigger valve located on or near the cutting handle.

In fact, a handle has been brought out which has this air jet feature an intregal part. The compressed air by combining mechanical action and oxidizing action removes the molten metal and slag at the pull of the trigger after the arc has melted the rivet head. Pressure of 50 to 100 pounds gives best satisfaction. Oxygen may be used for extra fine work, but in general, air is more economical.

AUTOMATIC ARC WELDING*

The limitations of hand welding with the metallic electrode are very widely known from the general application of this process. The maximum speed obtainable, the maximum current which can be used, the speed of deposition, etc., are matters of fairly general knowledge. These conditions are very largely limited by the physical condition of the operator in welding. His ability to hold a steady arc, which results in uniform deposition and avoids the breaking of the arc at frequent intervals, with conse-

**Written for The Welding Encylopedia by H. L. Unland.*

quent loss of time, is an important factor. At the same time he must be able to move the arc along the weld uniformly in order to deposit the metal smoothly and efficiently where required. On thin material, if the arc is held an instant too long at any one point, a hole will be burned through the sheet, and on thin metal it is practically impossible to fill up these holes, which involve the loss of the part, or an expensive patching job. On heavier work the continued strain of holding the arc, and intently watching the welding, together with the heat emitted, will cause a slowing down of speed throughout the day. If, now, a mechanical device can be used to feed the electrode wire and maintain uniform arc conditions at the same time as well as moving the arc uniformly along the weld, it is clear that the initial speed of welding can be maintained throughout the day. Further this uniformity permits the use of higher current values, and therefore higher welding speeds than hand welding.

In general the same conditions apply to automatic welding with the carbon electrode, but to a considerably less extent, since the arc length need not be maintained within the close limits required with the bare metallic electrode. Figure 1, shows a machine automatically welding thin sheet metal for transformer tanks. In this case the edges of the sheet are bent up and held together by suitable clamps. The arc passing along the joint fuses the edges together as shown in the sketch. This type of joint provides a rapid and convenient method of joining sheets without the use of added metal and can be applied in a great number of cases. Automatic carbon welding has also been applied to the welding of heavier metal both with and without the use of added filler metal.

Automatic welding with the bare metallic electrode is in more general use at present than any other method, and therefore the following will apply more directly to this method and its applications. The benefits of automatic welding to be aimed for are:

(1) Higher welding speed.
(2) Steadiness of electrical conditions in the arc.

The first point is important for economical reasons since higher speeds produce lower welding costs. The second point is necessary to produce a high quality of weld. Incidently the second point materially affects the first in that when the conditions are maintained uniform it is possible to speed up the welding, where as with hand welding increases in speed are very liable to cause a marked falling off in the quality of the weld.

In working out the application the second point must be considered first. In order to obtain the greatest benefit it is desirable that the electrode wire be a continuous length, which eliminates the waste ends ordinarily thrown away by hand welders, as well as the time taken in changing electrodes, and the restarting of the arc each time the electrode is changed. The most sensitive type of drive is a direct current shunt wound motor, which provides the greatest flexibility and adaptability. This particular device thus limits the application to direct current welding. To feed the wire a pair of rollers are required, one of which may be knurled so as to grip the wire more firmly. These rolls are geared to a small direct current motor wound for the proper voltage, which has its armature connected across the arc terminals. Other conditions remaining constant, the voltage across a welding arc will increase as the arc length is increased. If the motor armature is connected across the arc terminals an increase in the arc voltage will result in the motor speed increasing. With this motor connected by gearing to the feed rolls, the electrode will be fed more rapidly and will quickly return the arc voltage to normal. In case the wire burns too slowly and the arc is shortened the reverse action takes place.

The details of design of the welding head may vary widely, but fundamentally the automatic device consists of three portions, the electrode motor, the feed rolls, and the intermediate gearing. These may be mounted and grouped in a great many ways. The intermediate gearing should be so designed that the motor will operate over a reasonably small speed range. The rate of feed of electrode wire varies widely. For example, a 1/16-inch electrode may be fed three to four times as fast as a ⅛-inch electrode, when both electrodes are operated with economical values of current. It is not desirable to expect a motor to operate over this range of speed, obtained by field control, and still remain sensitive to the slight changes in voltage across the arc. Accordingly gear changes or combinations should be provided

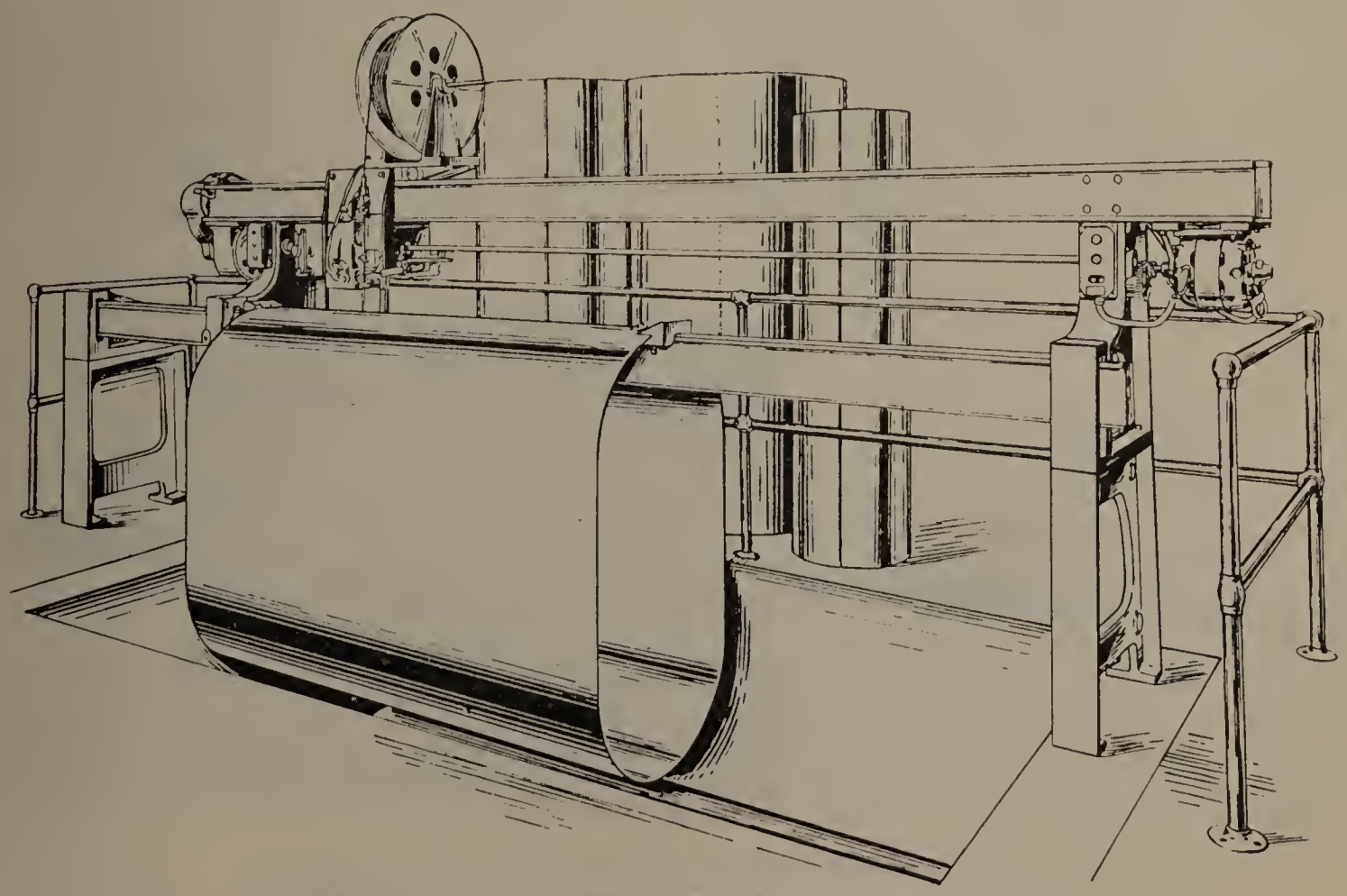


Fig. 1.—Automatic Welder for Welding Large Tanks.

for the various sizes of electrodes to be used, that is of course unless the head is intended to be used on only one single operation, and never applied for any other purpose. The control for the motor will vary widely in its details, depending somewhat on the type of welding circuit from which the automatic welder is to be operated. It should provide some means for slowly advancing the electrode to the work in commencing the weld, reversing the motor and withdrawing the electrode slightly, to establish an arc, and then advancing the electrode toward the work at the proper speed after the arc is established. Various combinations of contactors and relays have been provided for accomplishing this result, so that any diagram of connections would hardly be necessary or desirable, since they might be misleading.

In hand welding the operator manipulates the electrode, not only along the line of the weld, but with a circular or zig-zag motion from side to side across the weld so as to knit the two edges to be joined thoroughly. The automatic welder can be provided with a device for giving the oscillatory motion to the electrode where the welds are to be made on heavy metal or where the weld is to have considerable width. In hand welding, where the joint is not uniform, that is where the edges of the sheets or plates are not trimmed evenly, or they are bent, leaving unequal gaps between them, the welder will go slowly between these points, filling in more metal where required, and as the joint becomes narrower will increase the speed. The automatic welder however is unable to duplicate this performance and consequently in order to use it the seams and joints should be carefully prepared in order to provide a uniform width of joint at all points. This in some cases involves beveling the edges, and always involves clamping and supporting devices for holding the edges of the sheets to be joined rigidly in their proper relation. In the majority of applications the metal to be welded should be held solidly against a backing of metal, which will permit the use of higher welding currents, at the same time eliminating the possibility of molten metal from the sheets falling out, leaving a hole. It also improves the appearance of the under side of the joint.

Provisions should be made for moving the arc at a uniform speed along the line of the weld. This is purely a matter of relative movement, so that either the head or the work may be moved in order that the arc may progress along the weld. This movement is usually taken care of by means of a direct current adjustable speed motor, which combines the ability to provide a steady speed with the ability to adjust this speed over a wide range and within a close limits. The control for this motor may be interlocked with the control for the automatic welder so that the travel motor automatically starts when the arc is established and stops when the arc goes out.

A combination of these three factors, automatic welding head, clamping device, and the travel mechanism, necessitates practically a complete design for each individual application. Only a little consideration is necessary to see the difference in the requirements for welding cylindrical steel barrels and the welding on a rear axle housing for an automobile. In the first case only a straight linear seam is required for the side seam. For the end a circular seam is required, but in the case of the axle housing the weld must follow the contour of the housing which necessitates vertical movement of some part of the mechanism. An-

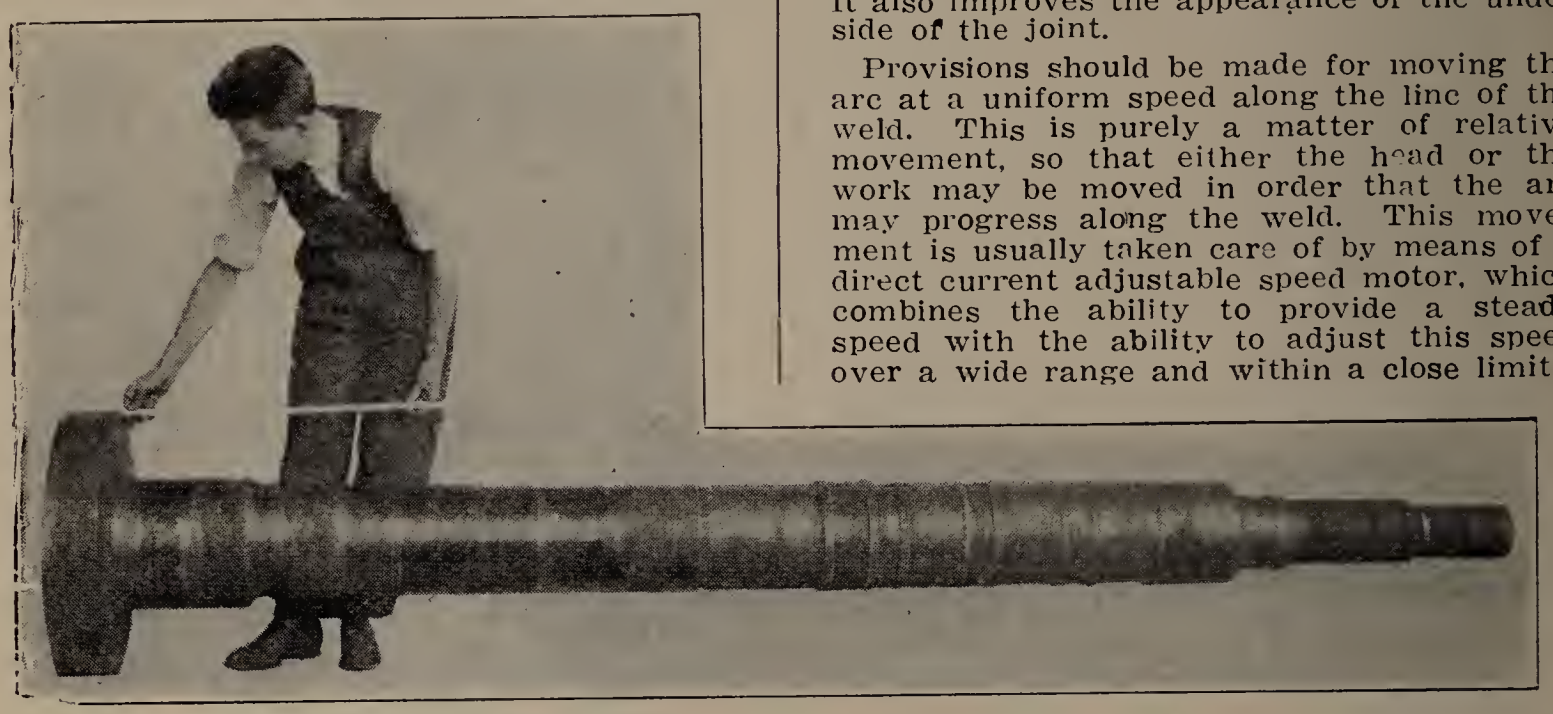


Fig. 2.—Incorrectly Machined Shoulders of Shaft Filled Up by Automatic Arc.

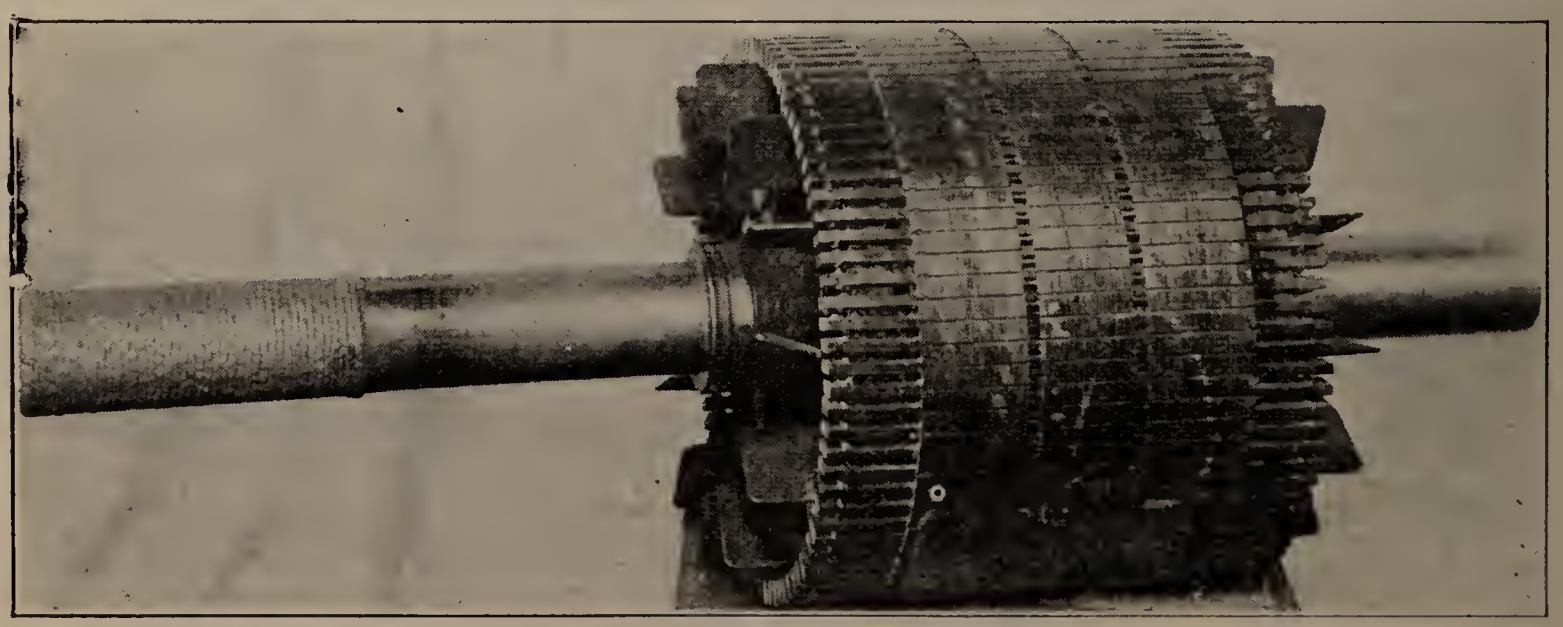


Fig. 3.—Induction Motor Shaft Built Up by Automatic Arc.

other application is the building up of worn shafting. In this case the weld is deposited in the form of a continuous spiral on the shaft or axle, which is built up above the required dimensions and reclaimed to size.

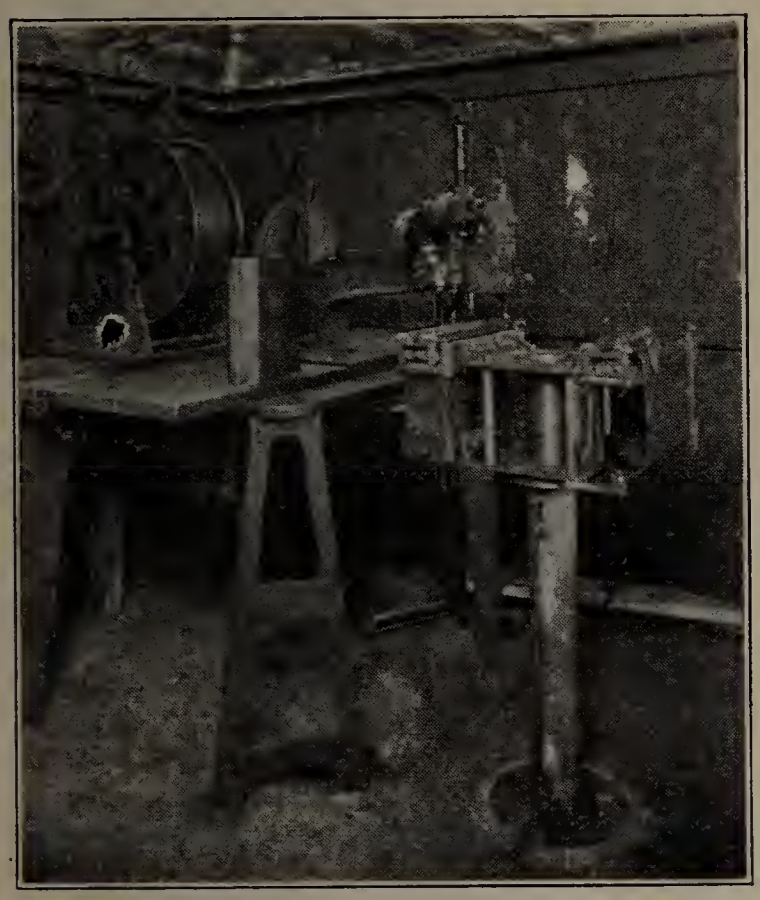


Fig. 4.—Automatic Arc Welder for Side Seams on Circuit Breaker Tanks.

Due to the concentration of heat it is possible to build up electric motor shafts without removing the rotating part from the shaft, or removing the winding.

In a simple building up job, it is possible to deposit up to four pounds of metal per hour on heavy pieces. The piece to be built up should be heavy enough to absorb and carry off the quantities of heat involved in continuous welding at this rate. This is shown by the illustrations of shafts which have been built up by the automatic welder. Solenoid brake wheels are being built of standard steel parts which are joined by means of the automatic welder. In welding tanks and barrels there is a great field for

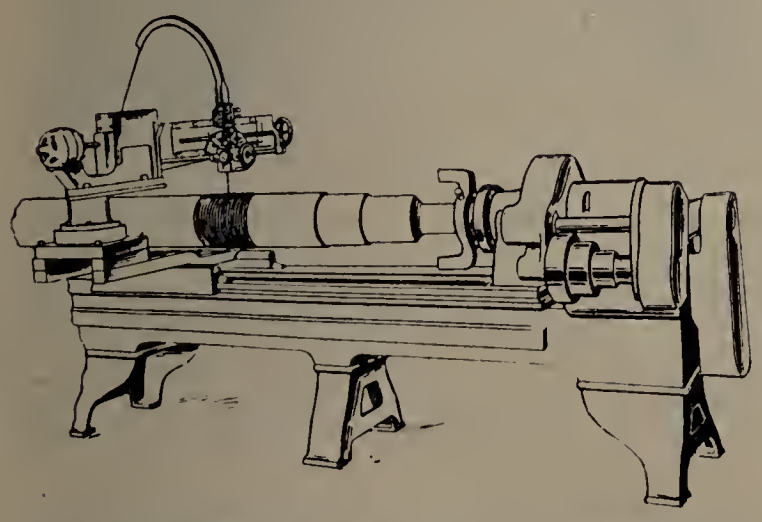


Fig. 6.—Figures 6 to 9 Show Several Methods of Utilizing Motions of a Turning Lathe to Obtain Travel in the Welding of Various Shapes with the Automatic Arc Welder.

the application of the process, a comparison of a day's output being shown by the size of the two stacks of oil switch tanks, the ratio being 2½ to 1, in favor of the automatic as compared with hand welding. The metal deposited has the same characteristics as that deposited by hand welding. It tends toward brittleness and will not stand any considerable deformation.

Since the use of automatic welding involves the use of more or less complicated and expensive accessory mechanisms, the

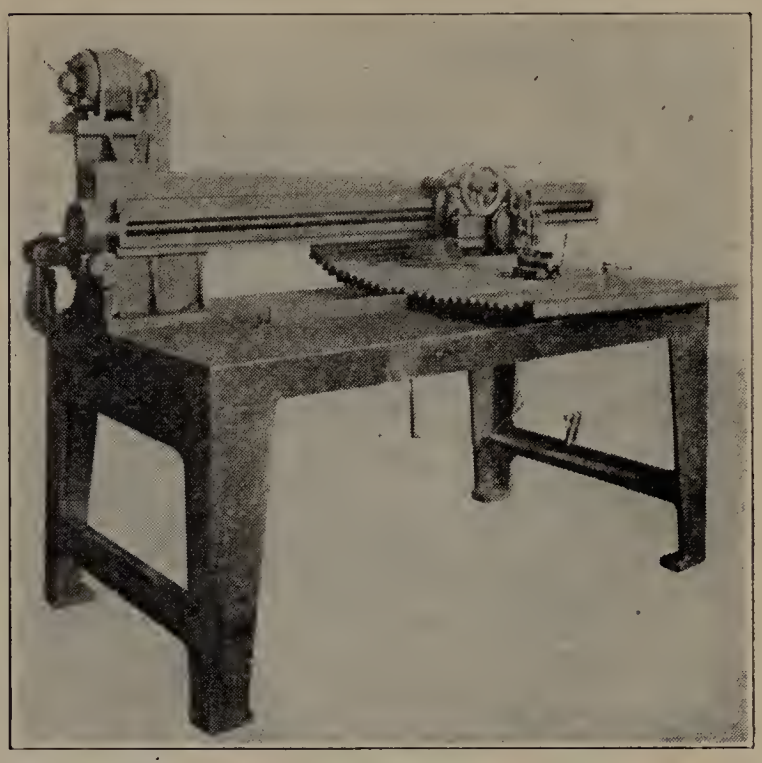


Fig. 5.—Automatic Welder for Thin Sheets—Carbon Arc.

application is justified only when the production conditions involve a large number of welds that are duplicated or nearly so. In this way it is very similar to some of the more complicated machine tools, such as turret lathes, screw machines, etc. The production with a given setup should be sufficient to return the investment costs in the equipment and the time involved in adjusting the equipment for successful operation on the required operation.

***Speed of welding in feet per hour**

Thickness of Metal	Hand Welding	Semi-Automatic Welding	Automatic Welding
1/16	x	25 to 50	50 to 100
1/8	7 to 16	15 to 30	30 to 50
3/16	6 to 12	12 to 25	20 to 35
1/4	5 to 10	8 to 15	10 to 25
3/8	3 to 5	5 to 8	5 to 8

*To reduce to inches per minute divide by five (5).
x Metal is too thin for hand welding on a production basis.

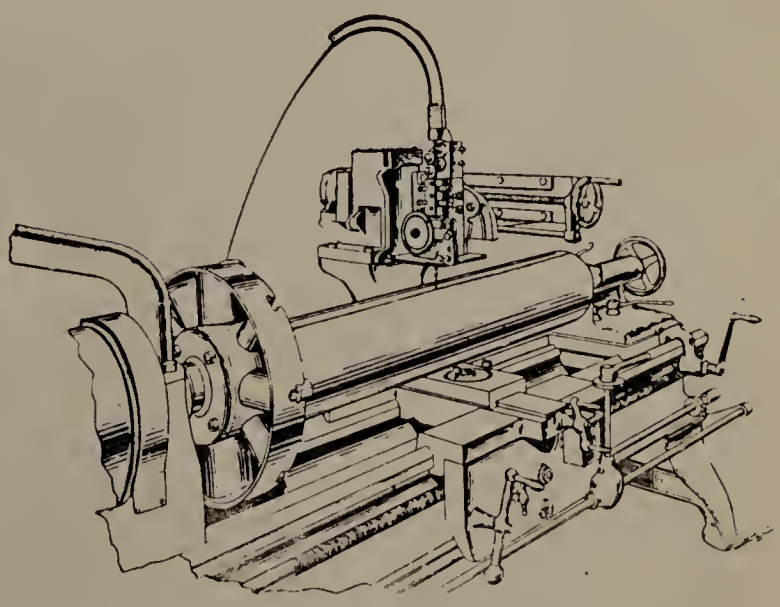


Fig. 9.

Semi-Automatic Welding

A number of welding applications involve all the requirements of automatic welding except that the size or weight of the pieces to be welded prohibits convenient handling.

clamping, and traveling. It may be that the contour of the seam to be welded is so irregular that it would be impossible, mechanically, to build a device for accurately following the seam at uniform speed. In such cases a device that would permit the operator to direct the arc as in hand welding,

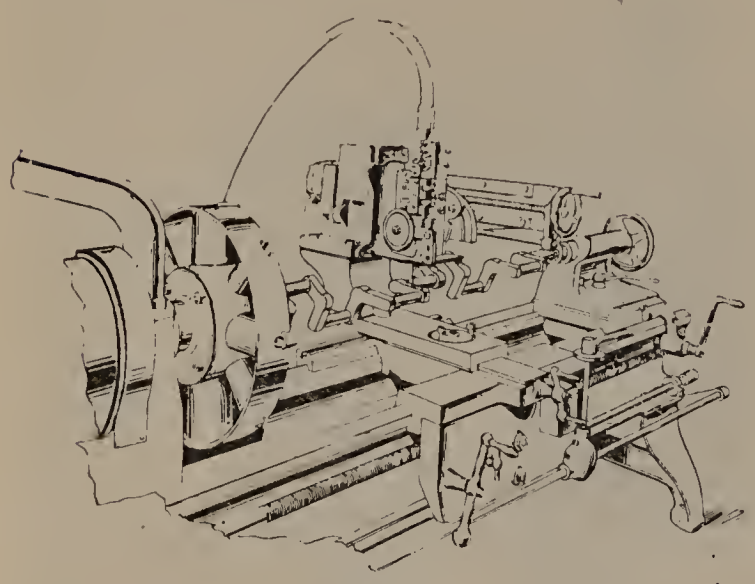


Fig. 7.

but which would automatically feed the electrode and maintain a steady arc would remove from the operator this portion of the muscular strain. Consequently it would permit the use of higher current values than hand welding will allow, while possibly not equalling those which might be used in full automatic welding. The semi-automatic

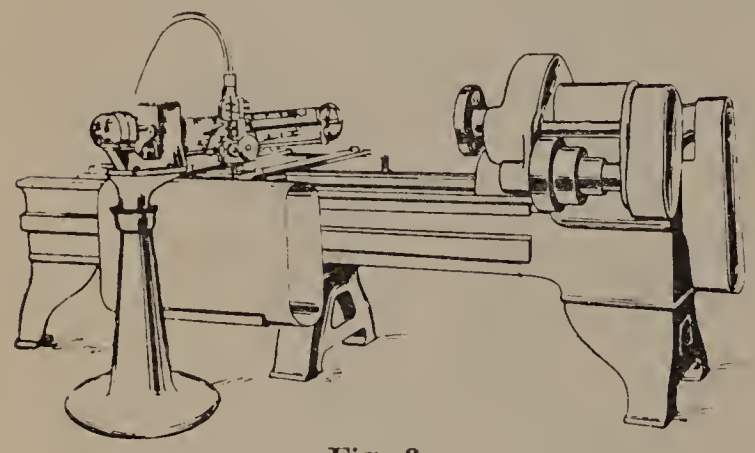


Fig. 8.

welder consists of a flexible metallic tube attached to an automatic welding head for receiving the electrode as it passes from the feed rolls. At the end of this flexible tube a nandle is provided, making it convenient for the operator to hold and direct the electrode wire at the arc. Current is introduced into this handle, or welding tool, as it is termed, so that only a short length of wire between the welding tool and the arc actually carries current. This reduces the heating in the electrode wire, and permits the use of high current. Where a long length of electrode wire is carrying current, it is being heated by the current during the time it passes from the point where the current is conveyed to it, to the arc. In many cases the temperature of the wire under these conditions reaches a point which renders it unsuitable for welding. It is very well known that electrode wire that is red hot will not establish and maintain an arc. With the semi-automatic arrangement, as in automatic welding the electrode is fed from a reel in one continuous length. so that the stub ends wasted in hand welding, and which amount to 15 per cent or more, are entirely avoided. The operator can weld at a higher rate for longer periods since he is very largely relieved of the muscular strain of holding a uniform short arc required for successful welding. Higher currents can be used which permit faster welding and higher rates of deposition.

With the semi-automatic attachment, clamping devices and backing for the welds may or may not be used as determined by the construction of any given application.

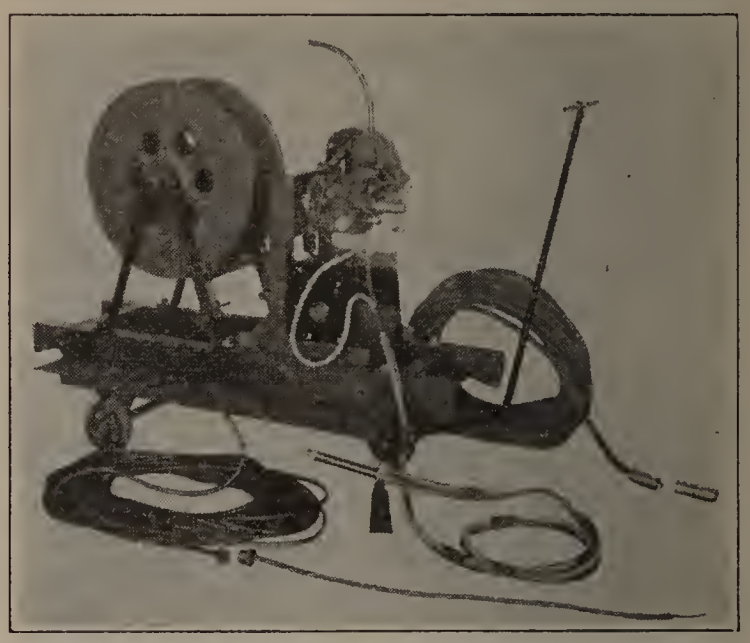


Fig. 10.—Portable Semi-Automatic Welding Machine.

The semi-automatic device may be constructed as an attachment to an automatic welder where it is desired, at times to use the semi-automatic process. The extra parts, including the guide and welding tool, can be attached to the welding head and the work performed at a distance up to 10 feet from

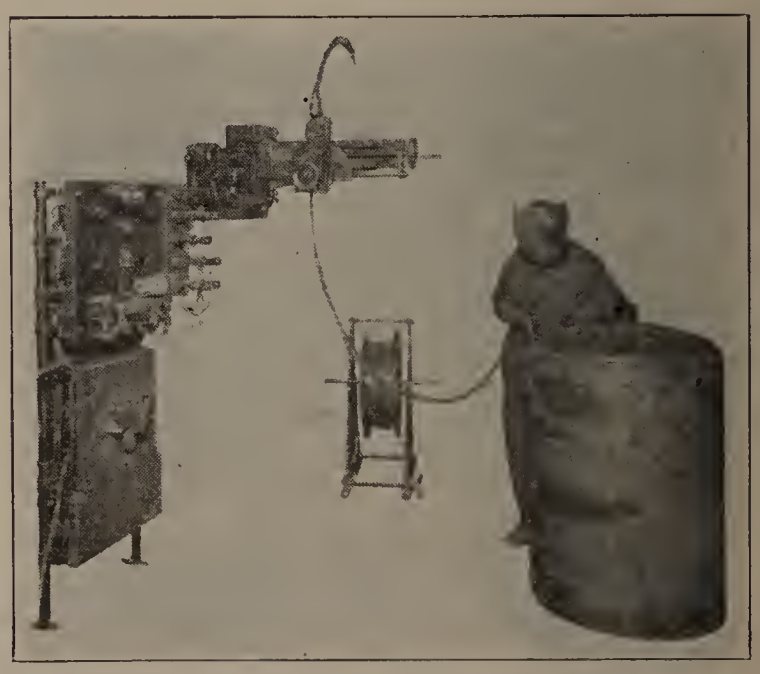


Fig. 11.—Stationary Semi-Automatic Arc Welder.

the welding head. The semi-automatic welder may also be constructed as a complete unit for semi-automatic welding only and mounted either in a portable or stationary form. depending on whether the work can be moved to the welder, or whether the welder must come to the work.

OXIDATION WITHIN THE ARC*

Oxidation of the metal passing thru a long arc is injurious to the efficiency of the weld. Metal at high temperature, particularly in the very finely divided state in which it passes thru the arc, has a very great affinity for oxygen. The arc stream is maintained in an atmosphere of oxygen and nitrogen and oxidation proceeds at a tremendous rate and the metal is bound to burn even in spite of its enormous velocity

**Written for The Welding Encyclopedia by E. Bauer.*

in passing thru the arc. Nitrogen will also be absorbed so that the metal as it solidifies on the weld will be permeated with iron oxide as well as included nitrogen.

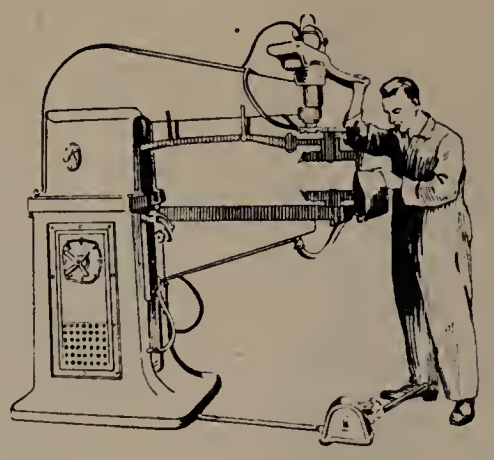
There has never been any experimental proof of included nitrogen causing weakness, as a break will invariably occur thru a line of oxide pockets. A long arc allows greater time for the arc metal to remain in contact with atmospheric gases and consequently causes more oxidation. The only way to combat the formation of oxide is by holding as short an arc as possible when ordinary bare electrodes are used. Experiments show, however, that the use of coated wire, the coating of which melts uniformly with the the wire, protecting the metal both on the plate and in the arc stream, results in a deposit of denser and more ductile metal. The coating also makes possible the use of a longer arc. But with bare wires the arc length should always be maintained as short as possible.

Ample proof of this theory is very easily obtained. A visual examination of the deposit from a long arc will show numerous small oxide inclusions at the surface and some of the deposit is readily brushed or chipped off. A more satisfying proof is obtained by building up two blocks of metal by the arc, each about an inch thick and about two or three inches square, one to be made using a short arc and the other a long arc. Each block is then sawed thru and the interior structures compared. The block made up using the short arc will be found to be solid and firm, while the other will show a structure with numerous oxide pockets and fine lines of included nitrogen.

Two test bars may be built up, one with a long arc and the other with a short arc, and each tested to destruction in a tension machine. The tensile strength of the bar made up with the long arc will in no way compare with that by the short arc.

ELECTRIC RESISTANCE WELDING

I. Introduction



OF all the uses to which the electric current has been put in late years, none perhaps is more important from a manufacturing point of view than that of electric resistance welding. Wherever one of the various methods of resistance welding can be applied a production problem is solved with a decrease in labor, dirt, noise and time, a simply operated and perfectly safe piece of machinery making joints silently and neatly, and with amazing rapidity. It would be extremely difficult, if at all possible, to enumerate all the lines of manufacture that have adopted electric resistance welding in one of its forms, but throughout this chapter an attempt will be made to show some of the general applications of its various forms to industry.

The theory of the resistance welding process is that the low voltage, high amperage electric current flows through a heavy copper conductor with comparative freedom until it reaches the work to be welded, which has been placed in its path, when, in its struggle to continue, owing to the greater resistance the material being welded offers to its passage, intense heat is generated, when at the proper time pressure is applied which forces the metals together resulting in a union of the two pieces, that is as strong as any part of the two pieces that have been thus joined. A feature of this process is that the heat is generated at the center of the material being welded, or at the point of contact, which is a condition that makes certain the proper union of the two, for by the time the outer surface has been heated, and the pressure applied, a perfect weld is sure to result, provided the machine used is properly constructed for handling the particular work being done and the operator understands how to regulate the heat, time and pressure.

Electric resistance welding is suitable only for duplicate or production work. In general one machine is designed for handling pieces of the same metal and for making joints of similar design. Repair jobs have been accomplished on them in special cases, but it is only in rare cases that such an adaption of the process is attempted. There is a certain degree of flexibility in the operation of a single machine, examples of which will be noted later in this chapter, but the reader should bear in mind that the use of this process is economical according to the volume of duplicate operations that can be made with it.

A resistance welding machine is simply a single phase transformer having a secondary of one or two turns, the voltage required between the terminals being only five to ten volts and the current being limited only by the size of the pieces to be handled. The transformer is built into a heavy frame which supports the clamping jaws to handle the work and mechanical devices to regulate the heat and pressure.

The electric resistance welding machine has in some instances reached a high degree of perfection and its use has resulted in large savings of time and labor in production. The principal involved has been applied in the construction of machines of differing design, giving a special nomenclature which will be outlined in the definitions that follow.

Butt Welding by the electric resistance method consists of joining pieces end to end, securing complete fusion of the entire cross section of the pieces, the line of weld being transverse to the length of the pieces, or its equivalent.

Line Welding by the electric resistance method consists of joining pieces along a continous line or seam, usually by moving the joint in the path of the current so that fusion is secured continuously or progressively.

Percussive Welding by the electric resistance method consists of bringing the pieces together sharply, and with considerable force, and discharging a heavy charge from an electric condenser through them at the moment of impact.

Spot Welding by the electric resistance method consists of welding sheets, strips, etc., in spots by bringing together and heating relatively small sections of the sheets between copper or other suitable electrode points under pressure.

Later in the chapter each of these processes will be described and illustrated, and special applications, advantages and disadvantages will be explained. Before taking up the individual processes, however, there remain a few general comments to be made on the subject of resistance welding.

For this type of welding a single phase alternating current of any commercial frequency is used. The transformer in the resistance welding machine will take the current from any ordinary shop circuit and reduce it to a suitable welding current. Direct current cannot be used because there is no way to reduce the voltage economically.

Something has been said of the flexibility of these machines. A large machine can be used to weld small work and a small machine can be used to weld large work; but the former would be wasteful if practiced to any considerable extent because machines built for light work are less expensive, and the latter entails the danger of burning out the transformer by the overload.

To anyone not acquainted with electrical theory it would seem that a current strong enough to generate the terrific heat required for welding would be very dangerous to the operator. Such an idea is absurd, as a matter of fact. The current used for the welding has a very low voltage, which could scarcely be felt.

The time required for electric resistance welding is very short. In most cases where the process is used this amounts to a few seconds or possibly a fraction of a second. In any case a joint can be made this way much more quickly than by any other method. This factor means economy in both labor and current consumption, as the current is turned off the instant the welding heat has been secured.

Although the range of applications runs all the way from the joining of fine wires to the joining of the heavy plates used in ship construction, resistance welding has not been fully developed. Electrical engineers are working on experiments to perfect apparatus for such jobs as welding long longitudinal seams in heavy tubes, spot-welding heavy plates and making joints between pieces of different metals and having different cross-section.

II. Butt Welding

Butt welding is the process of uniting wires, rods, bars, plates, tubes or pieces of similar shape, tranverse to their length, a general requirement being that the pieces have the same cross section at the joint. The pieces are brought into contact by mechanical devices and heat is generated at the point of contact by passing a heavy electric current through the pieces. A very short time is needed to bring the metal adjacent to the joint to a melting temperature, when pressure is applied to force the pieces together, the pressure and current being maintained only long enough to insure a perfect union of the pieces into a homogeneous mass.

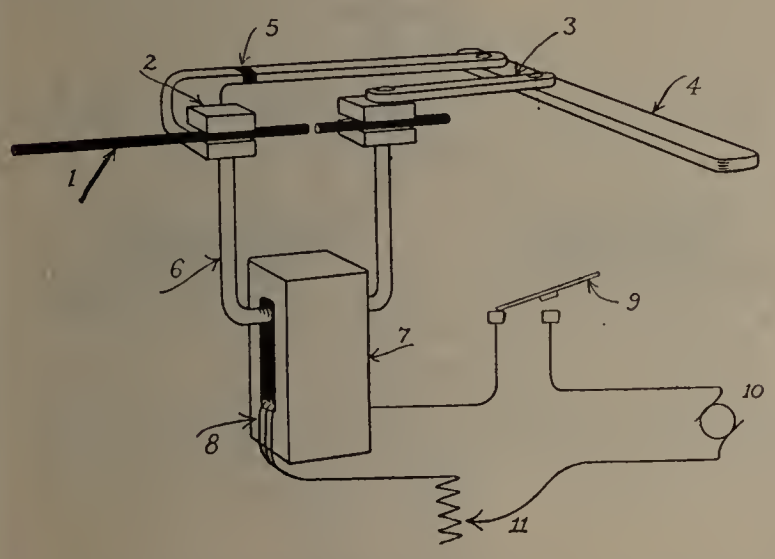


Figure 1.
1, Work; 2, Stationary Clamp; 3, Movable Clamp; 4, Lever; 5, Insulation; 6, Secondary; 7, Core of Transformer; 8, Primary; 9, Switch; 10, Alternator; 11, Variable Resistance.

In Figure 1 the important parts of an electric resistance butt welding machine are shown. The pieces to be welded are placed in the clamping jaws, one of which is stationary and the other movable. For light work the movable clamp can be operated by a hand lever, but for very heavy work this operation would be too hard on the welder and hydraulic or other mechanically applied pressure can be used. The alternating current is fed to the transformer and controlled by the insertion of a variable resistance. The secondary, or induced current, is taken from the transformer through a single turn of heavy copper cable. The insulation is provided to avoid short-circuiting the welding current away from the work.

Two butt welding machines may resemble each other very closely and still be adapted for widely different kinds of work. The construction of the clamping jaws, for example, varies for different metals and for different shapes of the same metal. The distance between the jaws is also a factor, as some pieces require heating through a larger portion of the metal than others, and in making joints between dissimilar metals, a point which will be discussed later, the one with the lower melting point must be made to project farther from the jaws. In all resistance welding machines, also, various devices are used to keep the clamping jaws cool, because they can very easily become overheated and are expensive to repair or replace. If the electrodes are not kept cool the heat will gradually work back to the transformer and reduce the efficiency. The simplest method of keeping them cool is to keep a current of cold water flowing through them constantly. It is very important that the transformer be designed to produce a current of the amperage required by the work, for if the pieces to be welded are uniform in material and design each welding operation will call for approximately the same amount of current.

Operation. Although the making of a butt weld by the resistance method does not call for the extremely careful preparation that is necessary with other welding processes, it should be noted that better results, from an economy standpoint, will be obtained if some attention is given to this point. Work that is very rusty or scaly will not weld so easily or so quickly, and the wear on the machine will be harder. The cost of smoothing and cleaning the parts is low compared to the savings that result from insisting upon the most favorable conditions for welding. It does not pay to try to weld a quantity of scaly stock without pickling. (See "Pickle.") Efficient operation demands that the parts be uniformly constructed and reasonably well prepared before bringing them to the machine.

Assuming then that the stock is ready, the two pieces are placed in the clamping jaws of the machine with a short section projecting beyond the edges of the jaws. The amount of projection is determined by the size and nature of the metals. If two pieces of the same metal but of different cross section are to be welded it is necessary to reduce the size of the larger piece for a distance equal to the length that is expected to be lost in making the weld. Enough pressure is exerted on the lever to bring the projecting portions into contact and then the current is turned on. The parts in the interval between the jaws immediately begin to heat. As soon as the welding temperature is reached the operator increases the pressure, thus forcing the pieces together, and turns off the current.

Careful experimenting is the only way to determine how to arrange the time, heat and pressure so that the metal is structurally the same in the weld as in the areas away from the influence of the weld. In the case of steel stock, experiments have resulted in the recommendation of the following conditions: that the surfaces in contact and the metal in the immediate vicinity of the weld be heated by the current to a temperature no higher than is customarily used in the smith shop for welding, i. e., 2200 to 2400 deg. F.* The temperature must not be applied any longer than is necessary to bring the metal immediately behind the surface to be welded up to the welding heat. The less the length of the bar heated for welding the better. The pressure applied during welding must be sufficient to force the metal into actual contact and slightly to deform it. At the temperature of welding the metal is plastic and the welding is accomplished by so pressing the plastic surfaces together that the grains of the metal are brought into such intimate contact that grain growth from one piece of metal to the other takes place. Welding made under these conditions is the duplicate of welding made in the smith shop. The experiments indicate that welds made with conditions such that a heavy flash is thrown out are a trifle weaker than the metal welded because of the structural change resulting from the decarbonization of the steel and because of the blowholes formed when the metal is welded.

When the weld is made with a high current applied for a relatively long period, which produces a high temperature existing over a considerable length of the bar, the result is a weld with a considerable movement of the clamps and an accompanying heavy flash around the weld. There is a considerable decarbonization of the steel in the immediate vicinity of the weld and the structure of the weld itself is irregular and ill-defined. In the immediate vicinity of the weld there will be evidence of overheating. Annealing restores the structure of the steel close to the weld but cannot completely restore the structure in the weld itself because of the decarbonization. A

**See Temperature-Color Chart.*

weld made under such conditions will be weaker than the remainder of the steel. judging from experimental data. Some users, however, claim that results secured in practice are in favor of the flash weld. The skillful operator is the one who knows when to turn off the current. This knowledge enables him to use less power and produce better welds.

Nearly all metals used commercially to

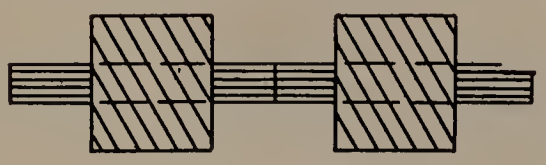


Figure 2.

any extent have been welded by this process. The following brief discussion will point out some of the methods used to accommodate the process to the varying char-

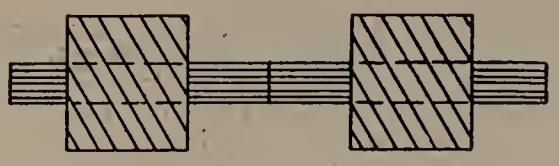


Figure 3.

acteristics of the more important metals.

Aluminum. This metal possesses almost no strength when heated to the welding temperature and the control of heat and pressure is almost too delicate to be trusted to any but the most skillful operators, so machines built for work on aluminum are

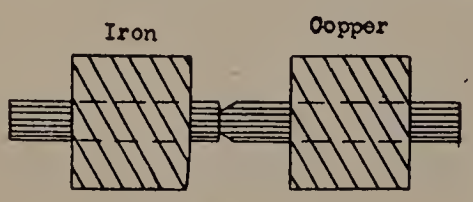


Figure 4.

usually provided with carefully adjusted automatic control.

Brass and Bronze. Brass is a very good conductor of electrical current, so only very small sections offer sufficient resistance to provide the welding heat. More allowance must also be made for loss in length, that is, a projection of about three times the

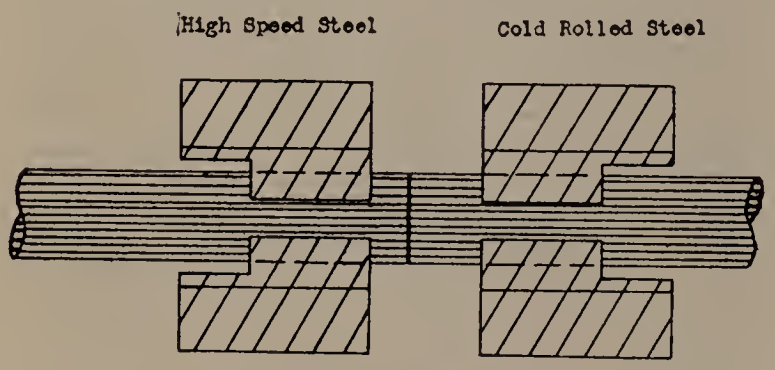


Figure 5.

diameter must be allowed between the clamps, as shown in Figure 2, though the relative projection can be decreased in the case of stock of more than one-fourth inch diameter. The metal is so difficult to handle that a very uniform pressure is needed, and this is best secured by means of a weight. The pressure should not be released until the weld has hardened enough to insure against cracking when it cools.

Cast Iron. Because it turns so quickly from a solid to a fluid when raised to high temperature, cast iron can be welded only in small sections.

Copper. The conditions are much the same as in welding brass. In the case of very small sections it is advisable that each end project twice its diameter from the clamps, as in Figure 3. Copper, brass and aluminum are such good conductors that they require a longer time to heat, and since they all flow so freely when heated to the melting temperature the pressure must be quick and not too severe. The correct application of pressure will force all

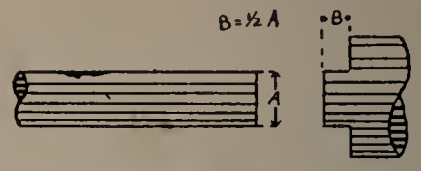


Figure 6.

the burnt metal out of the joint, giving a good sound weld. Copper has been successfully welded to wrought iron by using a tapered form to reduce the cross-section of the copper stock. (Figure 4).

High Speed Steel. One of the most ingenious applications of welding to economy in manufacturing is the great saving effected by welding high speed steel tips to common cold rolled steel shanks in the production of cutting tools. Many manufacturers of machine tools have taken up the electric resistance welding process for unit-

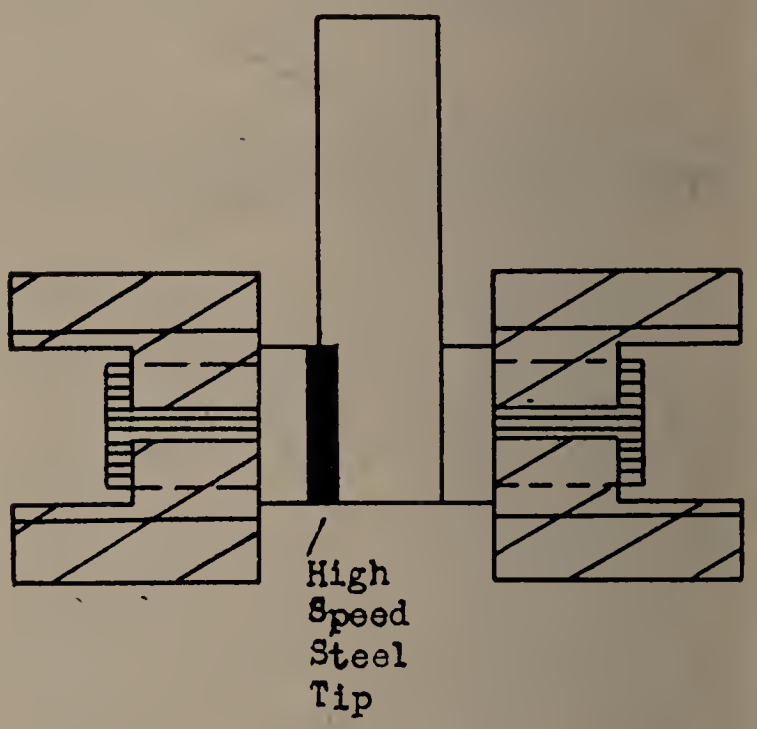


Figure 7.

ing the expensive cutting tips to cheap shanks and have found it successful. When this is to be done in a butt-welder the high speed steel tip should project about one-third as far from the clamp as the cold rolled steel shank, as shown in Figue 5. In case the two pieces are of unequal cross section it will be necessary to reduce the cross-section of the larger piece, as shown in Figure 6. Lathe and planer tools will sometimes have to be spot-welded, however, and in case there is no spot welder available a butt welder can be adapted to the work by the use of auxiliary dies. Figure 7 illustrates this. It is well known that no flux is necessary in resistance welding, but in this case the use of a borax solution for dipping the pieces will often improve the work. After the weld is completed the tool should be annealed immediately. The only way to anneal is to subject the entire piece to the treatment.

Some manufacturers who make tools this way in large quantities have large, well equipped furnaces especially built for annealing tools after welding. It is also well to give careful attention to the preparation of the pieces in this case. One manufacturer had been in the habit of preparing

all parts for the weld on a milling machine and it was suggested to him that he could make a big saving by using a grinder instead. He made the experiment but was careful to make thorough tests at the same time. The tools were dropped, after the weld had been completed, from a height of about three feet so that their ends struck on two stones set the right distance apart.

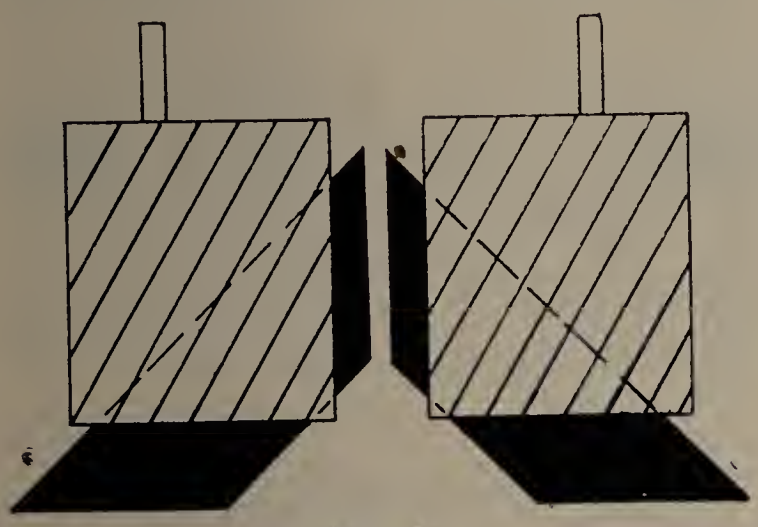


Figure 8.

He found that those which had been prepared by grinding resulted in nearly eighty-five per cent. failure, while those prepared by milling showed almost no failures, so few as to be negligible.

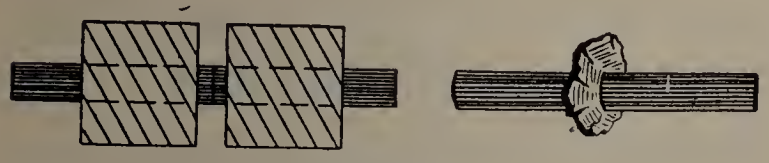


Figure 9.

Lead. Good work has been done in welding lead to tin and even in welding lead pipes end to end. The metal has a very low melting point and does not change color appreciably when approaching the welding heat, so the only index of its temperature condition is its plasticity. A better joint will be secured if the pieces are beveled to reduce the cross-section at the joint.

Steel. It has already been stated that in welding steel by this method the temper-

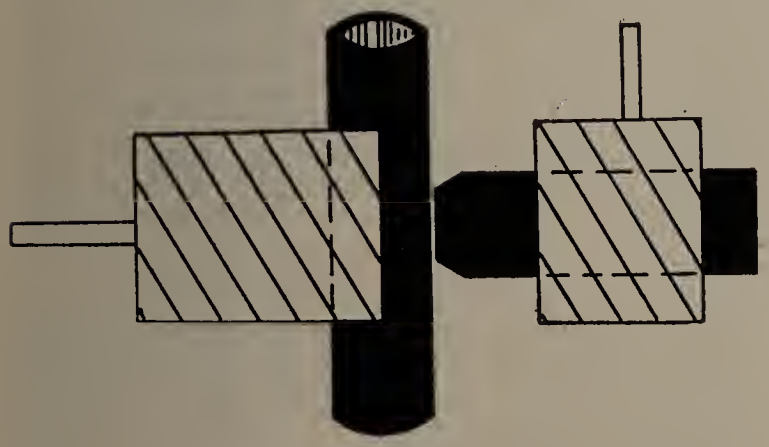


Figure 10.

ature must be kept below the melting point, which requires the use of considerable pressure to force the pieces together properly. In the case of steel wire there is danger of brittleness in the region of the weld, caused by the cooling effect of the clamping jaws, so machines built for this purpose are provided with a device for electrically annealing the wire for a short distance each side of the weld. The presence of a small percentage of nickel in the steel not only makes the welding easier but gives the piece more tensile strength.

Tin. Tin offers no difficulties but the pieces should be reduced in cross-section at the weld in order to decrease the amount of current needed for securing the welding heat.

Zinc. Welds under the same conditions as tin and is often welded in combination with the latter metal.

When welding non-ferrous metals oxidization and excessive heating can be prevented by playing upon the hot area a small jet of

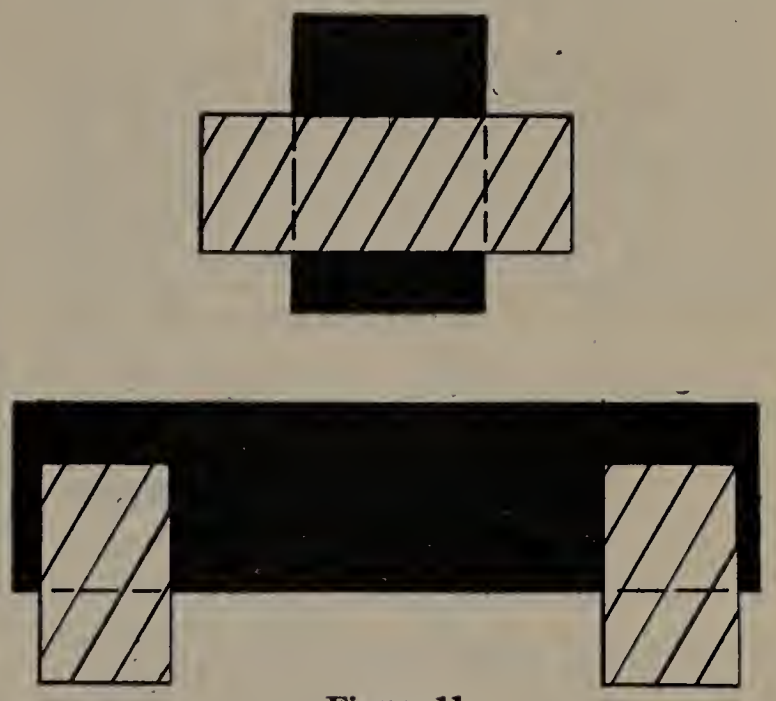


Figure 11.

water, which forms an envelope of superheated steam around the weld. The operator should try to avoid the use of too much pressure, as both time and material are saved by reducing the amount of "Flash".

When practicable the pieces to be butt welded should be of the same cross-sec-

Figure 12.

tional area if they are of the same metal. In case it is desired to weld unequal sections the larger one can be reduced, as recommended in the welding of high carbon steel tips to low carbon steel shanks, or the butt welder may be constructed with two transformers, one to supply current for heating the larger piece and the other to supply the welding current.

Many of the operations to be noted under "Spot Welding" can be performed on a butt welder by the use of auxiliary dies, as described in the welding of high speed steel. When welding copper, steel or brass this way one of the dies should be tapered, and both of them should be tapered for work on galvanized iron. Since butt welding is usually done with the work in a horizontal position and spot welding with the electrodes in a vertical position, this adaptation of the butt welder is limited to pieces that can be held in the required position without quickly tiring the operator.

Angle Welding. Straight bars can be welded to form any desired angle, and this work presents no difficulties provided the stock is carefully cut so that the machine will handle it smoothly. Figure 8 illustrates a good arrangement of clamps for making angle welds. Light tubing has been welded this way, in making windshields, with the exception that improved construction of the machines has made it unnecessary to mitre the pieces, the extra metal simply melting away. This greatly reduces the cost of preparing stock.

Automatic Butt Weld. This name is given to a butt weld made quickly, using high continuous contact pressure and heavy

current, the current being cut off by movement of the electrode or other means of control. Sometimes called Pressure Contact Weld.

Flash Weld. This name is given to a butt weld made quickly, starting with light contact pressure followed by a period of sparking with no pressure applied, and finished with heavy pressure, and by the use of enough heat to melt a portion of the metal, part of which is thrown out in the form of a burr.

When the burr is chipped off there is only a small area to be ground off if it is desired to have the whole piece smooth and of uniform thickness. Figure 9 shows how the metal should be held to produce a flash, and the appearance at the completion of the weld. The method is used on pieces that are thin or not carefully cut, on tubing, and on long, flat pieces.

Jump Weld. When rods, tubing, etc., are

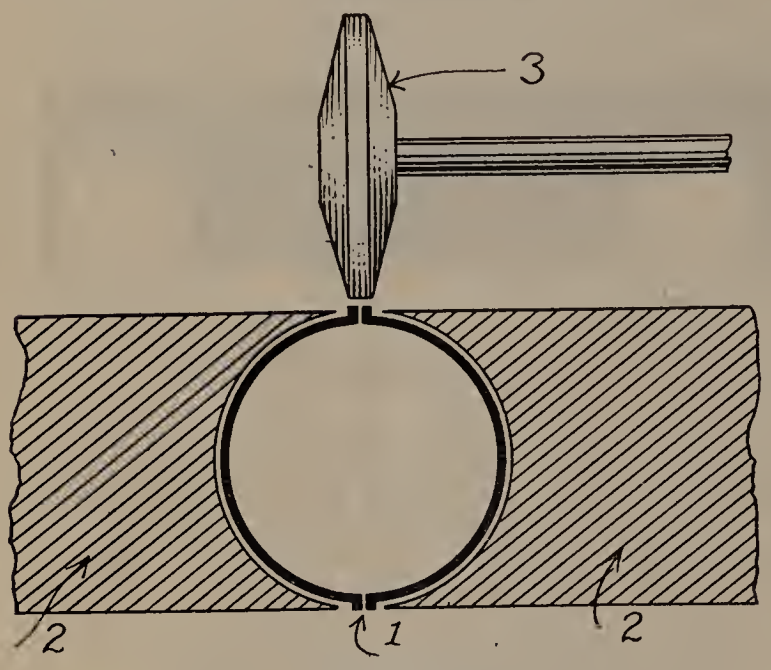


Figure 13.

1, Work; 2, Electrode-Clamp; 3, Electrode-Roller.

welded at right angles, in the form of a "T", the method is called jump welding. A high secondary voltage is used, and the weld is made instantaneously. Figure 10 shows how the work is held and how one of the pieces is tapered to increase the resistance.

Pressure Contact Weld. See "Automatic Butt Weld."

T-Weld. When it is desired to weld two flat strips together in the form of a T a special machine is necessary, for one of the pieces has to be held between two jaws as shown in Figure 11 and the area between the two jaws preheated by the current before the heat is applied to complete the weld between the two parts. A simpler and more popular method of preheating is described at the end of this chapter.

Upset Weld. A butt weld made with only enough heat to bring the pieces to a welding temperature and executed slowly with considerable pressure producing an upset at the joint. Figure 12 shows how the work should be held and how the upset weld looks. It does not give a uniform thickness to the finished piece but is considered stronger than a flash weld by some users. It is not suitable, however, for metals that are injured by high temperatures, for these must be well melted and forced together hard enough to throw out all the burnt metal from the joint.

Butt welding offers a number of advantages when the amount of work to be done justifies the investment in the machinery required. It is very rapid and requires little skill on the part of the operator. There is no waste of energy because the heat is generated within the metal and is used only as needed. The machine can be constructed to insure perfect alignment of the pieces without extra attention on the operator's part. The process is clean and quiet and the weld is always in full view. Finally, the resulting tensile strength at the joint is nearly as high, in some cases fully as high, as the strength of the pieces before welding, provided the work is annealed after welding.

Preheating Resistance Butt Welds

When butt weld is to be made between two pieces, one of which takes considerably longer to heat than the other, such as in making a Tee weld, a problem is encountered which cannot easily be solved by special construction of the machine. An easier solution is found in the preheating device illustrated by the sketch in Fig. 12A. This is simply a copper die large enough to span without touching it the piece which requires the least time to melt. Connection between the copper jaw holding that piece and the other piece of the work is thus formed, and the current is allowed to work only on the difficult piece. When the latter piece has nearly reached the melting point the pre-

Figure 14.

heater is removed and the two pieces to be welded are brought together and welded in the usual manner.

Operating Suggestions for Butt Welding

Unsatisfactory butt welding in plate stock can often be traced to careless cutting of the pieces, such as trimming one end squarely and leaving the other as it comes from the mill. A "cold weld" usually results, because when the work is clamped in the welder the abutting edges do not meet squarely but a V opening is formed. Then the heating does not start uniformly along the whole profile and one part of the weld is not brought up to welding heat until the very last moment before compression takes place, and, depending upon the amount of metal which is flashed off, it may have reached the welding heat and it may not. In connection with preparing the material, it has been suggested that plate edges be sheared on a slight bias so as to give a reduction of area, which cuts down the time required for heating, and to obviate the necessity for grinding off rusty mill edges. Grinding is often done so carelessly that thin edges are rounded off, taking away material from points where it is needed.

Crowding the capacity of a resistance welder is also to be avoided. Work should not be put on machines which heat it at too slow a rate, especially when the operator is working on a piecework basis. He is naturally anxious to get out as much work as he can, and if the machine does not work fast enough for him he may apply the pressure on a good many welds before they have been sufficiently heated. The result will be a high percentage of cracked welds.

The capacity of a butt welder is not completely determined by the cross sectional area of the stock to be welded; the shape of that cross section is an important factor. This is another reason for consulting an engineer skilled in the design and operation of such equipment whenever it is desired to make one welder handle a large variety of work. If the cross section is about the same in area but of different shape, it will probably be only a question of changing the clamping dies. Narrow welding jaws will

work with thin, flat stock, because it has a large area in contact with the jaws and the compression required for the weld is necessarily small owing to the spread of the material; hence the possibility of the stock slipping in the jaws during compression is very remote. When the sections are fairly condensed, however, there is a smaller area in contact with the clamping jaws and the compression force required is greater,

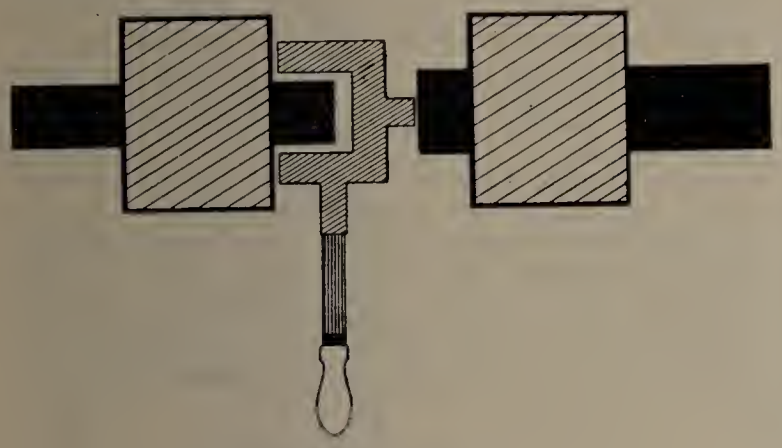


Figure 12A

so slipping is much more likely to occur. Therefore, in the case of such sections the clamps should be more substantial, though they must also be made easy to operate if rapid production is wanted.

Training of operators for electric butt welding is not a complicated process, but it is important that the few rules of operation be carefully observed, because incorrect operation will result in poor welds and also in a slowing up of the process. The welder who moves the plates faster than the metal is capable of being flashed off will find that he is welding the abutting faces at several points and then the flashing ceases; in other words, he gets stuck. Then he has to tear the joint apart and start all over again. There are three important results of this sort of poor workmanship; first, a loss of time and current; second, burned zones in the weld, which weaken it; third, the welding equipment is placed under an abnormal strain, which is not good for it. It is, therefore, quite in order to give the "human element" due consideration in resistance welding, and to provide supervision by someone capable of weeding out the inefficient and careless operators. When very heavy stock is involved the operator is not always to be blamed, since there is a limit to human endurance, and in this case mechanical compression devices and mechanically locked clamping devices can be added. If properly designed they will improve the product, shorten the welding time, and save the operator a great deal of effort.

III. LINE WELDING

This process somewhat combines the features of butt welding and spot-welding. It is used for jointing together two metal sheets or plates end to end, or in a continuous line, as in the longitudinal seam of a metal tube. "Seam welding" is another name commonly applied to the work.

Machinery for line welding by the electric resistance method has been developed very successfully, but is limited to work on light stock and short seams, although it is known that a few of the manufacturers of steel tubing have perfected special machines for their own use that greatly reduce the cost of manufacturing. However, there are plenty of cases where electrically welded seams on light stock mean more economical production. The standard line welders usually are equipped with two electrodes fashioned as in Figure 13 and 14. In Figure 13 one of the electrodes is a roller and the other is connected to the work, the roller running over the seam. Figure 14 shows both electrodes as converging rollers, with the converging edges resting on opposite parts of the work, near the edge to be welded. It will be noticed that this arrangement is easily adapted to either welding flat sheets or tubes. In both illustrations the work is shown in cross section. The work is passed beneath the rollers, which carry the current into the metal and make the weld in a continuous line.

This is a rapid and economical way of making seam or line welds on sheet steel or sheet brass of small dimensions. With a careless operator, or a machine that is not adapted to the stock, holes will be found where the electrodes have skipped. The stock has to be very carefully cleaned and be securely held by the machine to get good welds.

Bridge Seam Weld. When edges are butted together and a strip or sheet is welded over this joint the weld is called a Bridge Seam Weld.

Butt Seam Weld. When the pieces meet edge to edge and are progressively butt welded, the weld is termed a Butt Seam Weld. Usually two rollers of copper supply the current.

Lap Seam Weld. When the seam weld is made in the form of a lap joint, the weld is called a Lap Seam Weld. Current may be supplied by two rollers or one roller and one stationary contact.

IV. ELECTRO-PERCUSSIVE WELDING*

Electro-percussive welding is a process of electrically welding separated metal parts by means of a sudden discharge of electrical energy at the junction in an arc which is extinguished by a percussive blow applied simultaneously or immediately following.

Electrostatic Weld. When the discharge of a condenser is used to supply the arc energy the weld is termed an electrostatic weld.

Electromagnetic Weld. When the stored energy in a magnetic field is transformed to electrical energy by collapse of the field to supply the arc energy, the weld is termed an Electromagnetic Weld.

Electro-percussive welding is a process which is primarily intended for manufacturing applications, where large quantities of duplicate parts are to be produced. One size of machine will handle a large variety of pieces over quite a range of size but it will be appreciated that more or less special holding fixtures must be designed to attach to a given machine. If only a small number of parts of each particular design and size is to be made, the necessary investment in fixtures may be excessive. Thus it will be apparent that repair work is not the most suitable field.

There is unlimited opportunity for development of automatic machines utilizing this process. Inasmuch as the time of welding is negligible, the only limitation of speed of production is speed of feeding and gripping the pieces. This permits a heretofore impossible output. Furthermore, unskilled labor can be used.

Suggestive of the type of applications determined to be suitable are the following:

Automobile Parts. Study of parts used in the construction of a prominent make of car, showed over 50 important parts where percussive welding would demonstrate a decided advantage over present methods.

Tools. Manufacturing costs of many types of tools using a special cutting portion attached to a cheaper grade shank would be reduced and better results obtained.

Hardware. There are countless items of hardware involving especially union of unlike metals or unequal sections which offer great possibilities.

The underlying principles utilized in percussive welding were discovered in 1905 by Mr. J. W. Chubb, of the Westinghouse Company. Following his original experiments Mr.

**Written for the American Welding Society by Douglas F. Miner.*

Chubb developed machines for welding metals in wire form of rather small cross-section. With this equipment, very satisfactory welds were made between wires of various metals. Widely different physical properties of wires to be welded, offered no obstacle and perfectly ductile welds were made with platinum and lead, tungsten and aluminum, copper and aluminum.

The Apparatus. The apparatus consists essentially of a device for producing a percussive engagement of parts to be welded, practically simultaneous with a discharge of electrical energy. In the wire welders the energy is taken from an electrolytic condenser. Sets of aluminum plates immersed in an electrolyte of borax solution are charged by a direct current of very small value and discharged at the moment of weld. This discharge takes place at the parts to be joined and melts them with an explosive violence. At this moment the hammer forges the parts together into a perfect union. Fusing and union of the metals is finished in

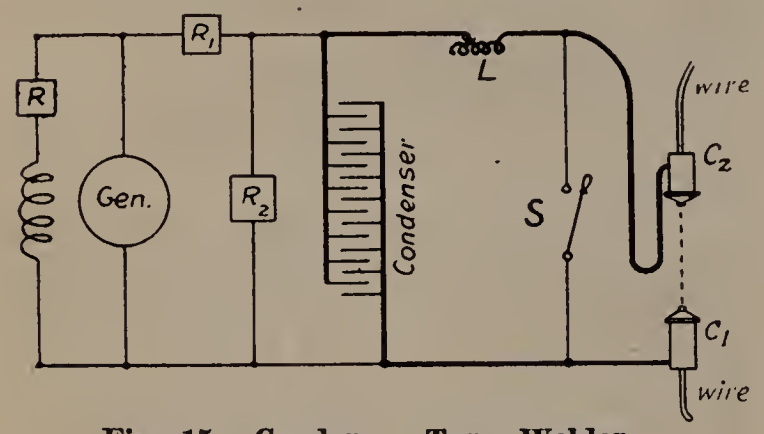


Fig. 15.—Condenser Type Welder.

approximately .005 second. Fig. 15 shows a circuit diagram of this process.

Using an electrolytic condenser for source of fusing energy proved to have decided limitations because of limited amount of energy capable of being stored in a condenser of convenient size. Consequently, Mr. Chubb evolved a scheme for utilizing electrical energy stored in a magnetic field, thus substituting electro-magnetic energy for electro-static. Since about the year 1919, experiments have developed apparatus along this line which have been very successful in welds of the butt type up to a cross-sectional area equivalent to ½-inch diameter stock. Future work will extend this to much larger sections.

Description of Apparatus. To give a better understanding of the process, we may briefly describe the operation of an experimental outfit. Fig. 16 is a diagram of electrical circuits.

Stated in simple terms, when any electrical circuit containing large inductance, such as a coil of many turns is interrupted, the stored energy of course tries to prevent the break and causes an arc to be drawn. An electric arc is a source of high intensity heat particularly well suited to welding operations. In an apparatus we have a reactance coil of two windings, one (primary) being connected momentarily to a source of direct current and the other (secondary) being connected to the pieces to be welded. By means of suitable tripping devices, the forging hammer causes the primary coil to be disconnected from the source of power, with the secondary closed. Transfer of energy of the collapsing magnetic field to the secondary occurs and then a rapid small separation of the parts to be welded causes an intense arc to melt the surfaces. At the proper moment the hammer forges the pieces together. The complete operation occupies about 0.1 second of time, giving no time for oxidation or excessive heating. The time sequence of events shown on oscillogram taken during a weld between ⅜-inch copper and steel rod indicates a peak of current of 2600 amperes, an arc voltage of 30, maximum power 60 kw., energy, .00077 kw.-hr., and time .094 seconds.

Advantages of Process. Some of the points of superiority which electro-percussive welding has are as follows:

(a) **Power Saved.** The power consumed at the weld by percussive welding is about one-sixth that required for same size stock by butt-welding, but this ratio could not be fully realized at the source of power due to the primary loss during establishment of field. Manipulation of circuits probably cannot be accomplished quickly enough to store exactly correct energy necessary, but at least ¾ power could be saved over butt-welding.

(b) **Time.** The operation is so rapid that the time of actual weld is negligible. Speed of production will, therefore, depend chiefly on the time of handling pieces. Saving along this line, of course, can be effected through automatic or semi-automatic devices. A time study of a number of operations employing other methods of welding has shown

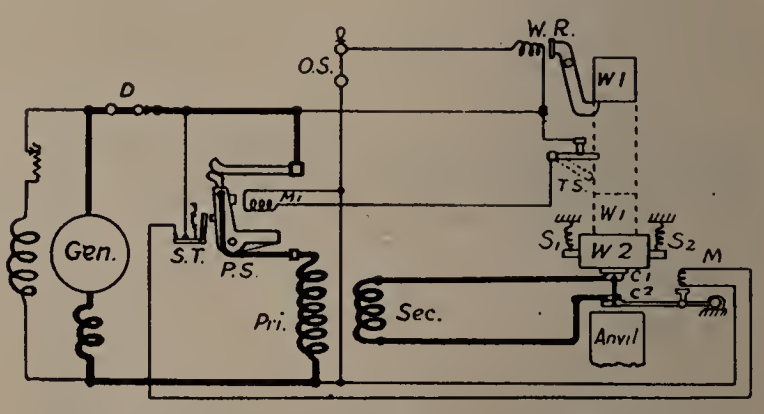


Fig. 16.—Electromagnetic Type Welder.

that the saving in time by the use of percussive welding promises to be a large item which will allow a remarkable increase in production or reduction in labor charges.

(c) **Welds of Unequal Sections.** The extremely short duration of the fusing arc in the percussive process allows no chance for the heat to travel back into the metal. The necessary energy is concentrated in a very small amount of material utilized where needed, and not dissipated in heating up the rest of the stock. Consequently, welds of unequal section are possible, such as a small rod to a heavy plate or a tube to a block. No preparation of the surfaces or previous treatment is necessary. Such welds, in order to be successful with other processes, necessitates either a preheating of the larger section or a modification of its shape, such as forming a projection of cross section equal to the smaller piece. This feature opens up a wide field of application allowing welding of some products formerly impossible, and greatly improving methods of manufacture on some products now employing other welding processes with special treatment.

(d) **Welds of Unlike Metals.** Just as the condenser type of welder produced welds with metals of widely different physical characteristics, the electro-magnetic type is also successful with such unions. Many of these were heretofore impossible. In many manufactured products it is desirable to join brass or copper parts used for electrical circuits or for appearance to parts composed of steel used for its strength or cheapness. Percussive welding solves many of these problems without the use of screws, bolts or rivets.

(e) **Welds Without Change of Condition.** Percussive welding makes possible welds of parts in which the heating caused by other methods would either destroy the physical structure of the metal or would change its condition such as drawing the temper. Welds can be made after any desired treatment without change of condition, because of the localized heat of the weld. Immedi-

ately after the weld is complete the piece can be handled and no appreciable warmth can be felt. Tool manufacturers are aided, by this valuable feature.

(f) **Welds Uniform.** After the proper setting for a given weld is made, the character of the weld is always uniform and independent of the skill of the operator. The original settings made in accordance with a convenient table of values permit operation of the machine by unskilled labor without fear of poor results. With most other welding processes, the judgment of the operator must be relied upon to a large extent and chance of faulty work is large.

(g) **Finishing.** The percussive process produces a much smaller fin or flash than butt-welding, thereby decreasing cost of finishing. For many purposes no finishing operations are necessary. Recent results have indicated that percussive welding has many wonderful applications and will solve difficulties heretofore encountered, especially in

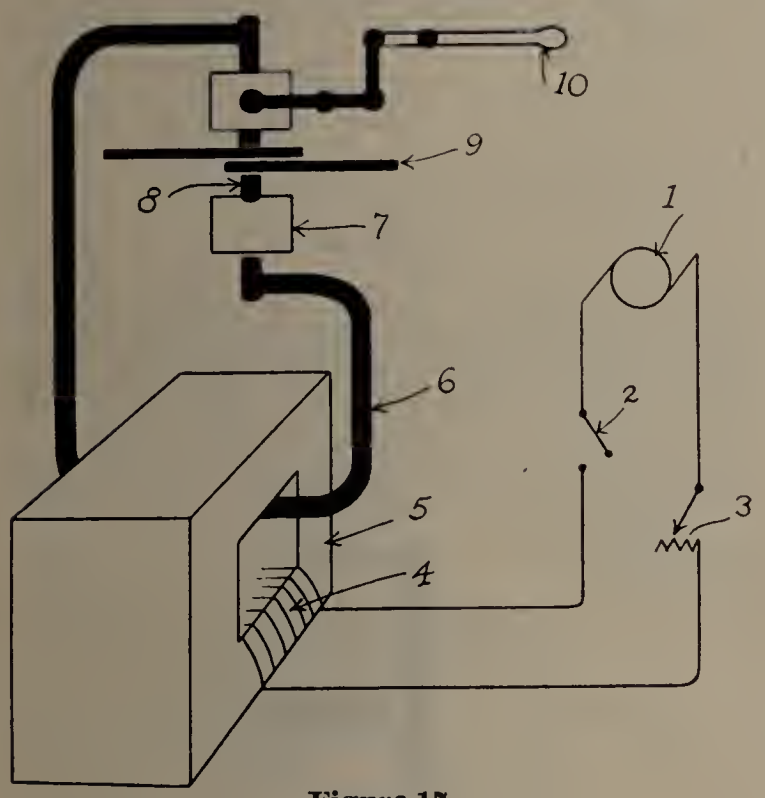


Figure 17.

1, Alternator; 2, Switch; 3, Variable Resistance; 4, Primary; 5, Core; 6, Secondary; 7, Electrode Holder; 8, Electrode; 9, Work; 10, Lever.

non-ferrous and steel alloy welding. It is entirely possible also that the process may be extended to other types of joint than simple butt. Tests have indicated that applications in a wide variety of industries are available and it is hoped to increase the scope of the process in a large measure.

V. SPOT WELDING

In spot-welding the material is placed between copper die points supported on the ends of two arms, and the points are brought firmly together on the metal by the use of either foot or motive power. The current is then turned on. Copper being a good conductor, provides an easy path for the flow of the current, which, however, must pass through the metal to be welded to complete the circuit. This metal is a poor conductor, and in attempting to carry the large volume of current, becomes heated, and when heated to a sufficient degree, pressure is applied either by hand, foot or automatically, and the weld completed. Fig. 17 is a diagram of the essential parts of a spot welding machine.

In case of automatic control, the current is turned on and off and the necessary welding pressure automatically applied by the controlling mechanism, driven preferably by a variable-speed motor. In this process the nicety of electric control is completely demonstrated. The current is applied to a certain definite spot only, and in just the quantity and for the length of time desired. On account of the intense heat and the rapidity with which it can be generated, several thousand welds per hour can be made in small, light stock but the number for the heavier and more bulky stock is more limited on account of the time taken to adjust it in the machine and additional time necessary to complete the weld.

Practically all spot welding is done on sheet stock, mostly on the smaller thicknesses, and there is consequently little difference in the preparation and execution of the work. Difficulties will be encountered if it is attempted to weld shapes that surround one of the electrodes, as in welding spots along the seam of a tube. In this case an induced current is set up in the metal, which means that the electrode affected is robbed of some of the electrical energy that is supplied to it for welding. The condition cannot be overcome in any practical way so the machine simply has to be made to supply heavier current than would ordinarily be required for the size stock used. More current will also be required unless the stock is thoroughly cleaned before being brought to the machine, but the sensible thing to do is to **have the stock clean.** It should also be perfectly flat, that is, free from bumps or dents, so that a good close contact can be secured without the use of too much mechanical pressure. The electrodes should be called upon to exert as little pressure as possible, as they are usually made of copper or a copper alloy and wear out easily. The electrode points of a spot welder are the only parts that require very much in the way of replacement or repair.

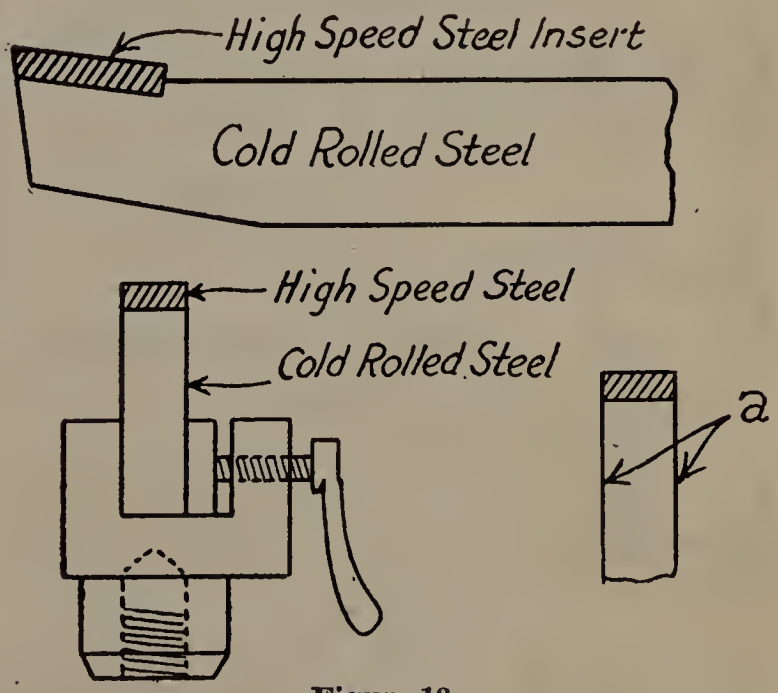


Figure 18.

It will be noticed in the following paragraphs that metals to be spot welded must offer considerable resistance to the electric current. This is because sufficient heat cannot be generated without this resistance.

Aluminum. This is an excellent conductor and a difficult metal to weld by any except the percussion process. If mixed with iron or zinc, however, the alloy can be welded very well.

Brass. Sheets of this metal can be welded to steel or to each other, provided the percentage of copper is not more than 60. The same applies to bronze, or other copper alloys.

Copper. No good results can be obtained with copper, either welded to copper or to some form of iron or steel.

Galvanized Iron. A little longer time is required for spot welding galvanized iron sheets, than is the case with other forms of iron, but a very good weld can be obtained. There is danger of burning holes through the metal if the process is attempted with very thin stock, however. The work should not be attempted on galvanized stock smaller than 24 gauge.

German Silver. If the machine is constructed so that the welding heat is reached very quickly, no difficulty will be experienced in making good welds.

High Speed Steel. The subject of welding high speed steel tips on cold rolled steel shanks has been discussed in the previous section on butt welding. This operation is done on a spot welder when the tips are for lathe and planer tools, as a very little bit of high speed steel is needed. When

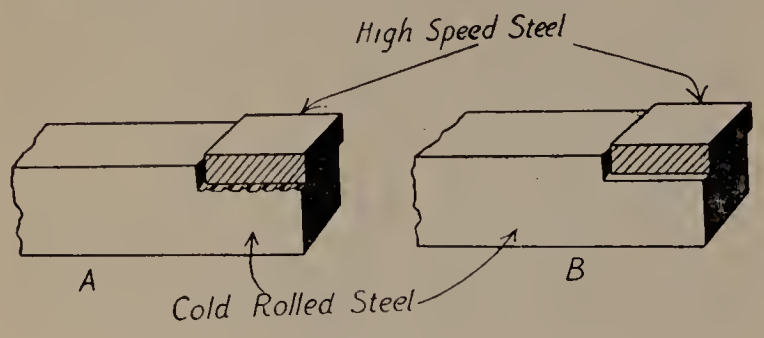


Figure 19.

the weld is well made these tools can be used until the tip is worn down to the thinness of paper. When making them, however, the tool steel should be from one-fourth to one-third the thickness of the tool at the weld. This is because the high speed

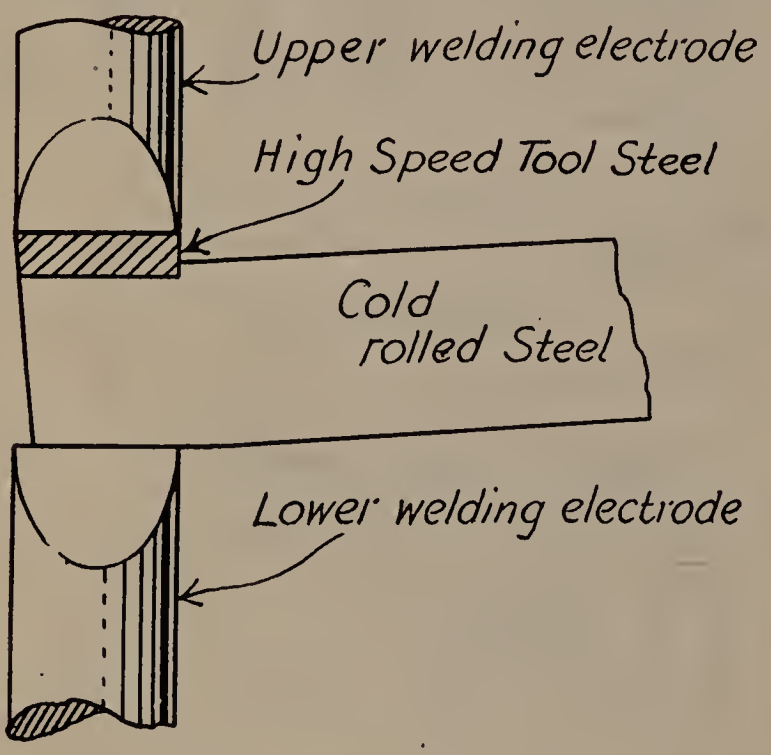


Figure 20.

steel offers a greater resistance to the current and consequently heats more quickly. The current is cut off when the welding heat is reached, and heavy pressure applied to force the pieces together. In doing this sort of work the heat and pressure is so

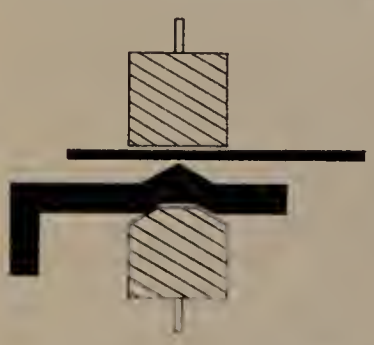


Figure 21.

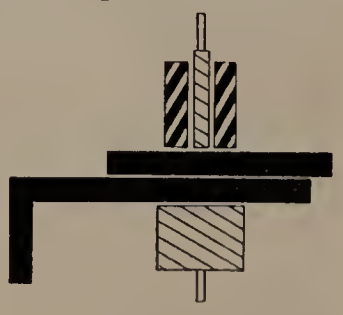


Figure 22.

hard on the copper electrodes that it is well to have them cooled by a current of water running through them. Figure 18 shows a clamping device that can be used in cases when it is necessary to have the high speed steel tip thinner than the proportions mentioned above. This will prevent the low carbon steel from heating too rapidly at the point "A" and then bulging when the pressure is applied. Figure 19 illustrates a method of grooving the metal when the pieces are thick, in order to localize the current and cut down the amount of current needed. The method of making the weld is shown in Figure 20. The special points to be observed are to have the parts clean and be sure that they are sufficiently heated before applying the pressure.

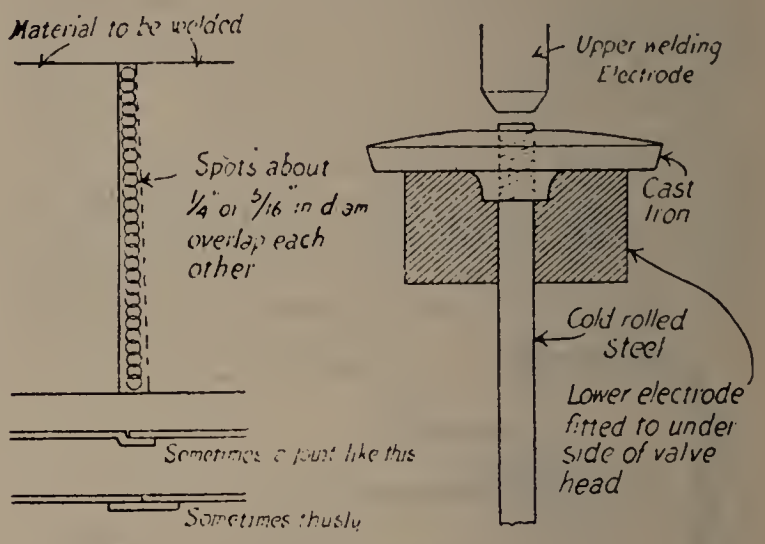


Figure 23.

Iron and Steel. Nearly all grades of iron and steel can be spot welded. Good results have been obtained during the war with welding heavy ship plate instead of riveting.

Monel Metal. Same as German Silver.

Tin. Sheet tin can be welded very fast and very well on a spot welder. The same is true of tinned sheet iron.

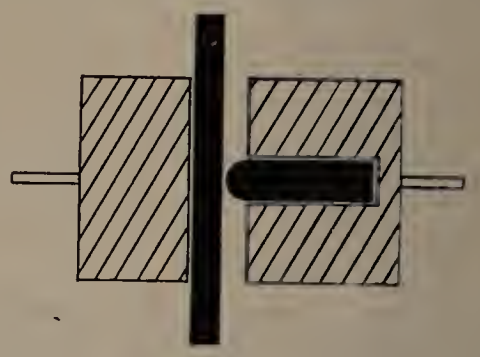


Figure 24.

Zinc. Same as German Silver. Use less time and less pressure than in welding iron and steel.

Variations in the composition, shape and thickness of materials call for the display of considerable ingenuity in reducing the expense of welding and increasing the quality of the weld itself. If one of the pieces is thicker than the other, Figure 21 illustrates a good method of preparing the work.

Figure 25.

Without the use of some such device the thinner piece would heat much faster and be burned before the thick piece reached the welding temperature, resulting in an imperfect weld and a weakened structure.

Figure 22 shows a heavy steel collar arranged outside the upper electrode to force heavy plate metal together before applying the current.

During the past four years the call for spot welding of thick plate, as in the construction of freight cars and ships, has been met by the construction of extra large machines capable of supplying a welding cur-

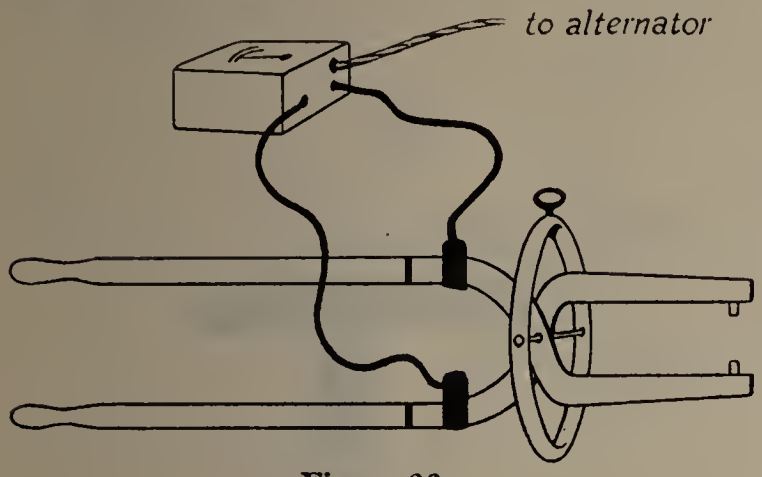


Figure 26.

rent up to 100,000 amperes, and equipped to exert pressure up to 30,000 pounds per square inch on each spot. In welding such heavy work the plates are not cleaned at the joint, but only on the side that is in contact with the electrodes. The electrodes themselves gave considerable trouble because they wear out so easily on heavy duty. This difficulty was overcome by covering the

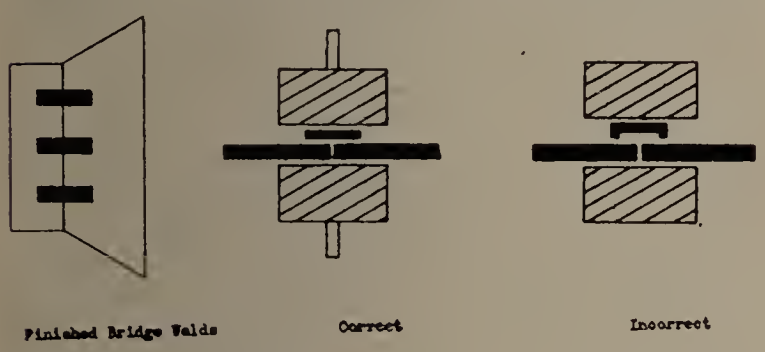


Figure 27.

electrodes with a thin copper cap, which was easy to replace and inexpensive.

Thin sheets are of course the simplest to weld. Figure 23 shows at the left two ways of arranging the material and one method of overlapping the spots to secure a continuous joint, and at the right a butt welding operation performed on a spot welder. Automatic machines are constructed to make these welds with astonishing rapidity. Using the automatic machine, the operator

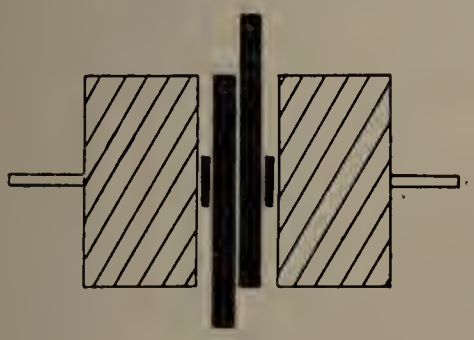


Figure 28.

presses his foot on the treadle once and the machine makes one weld, but if he holds his foot on the switch one weld will follow another at regular intervals, depending on the speed for which the machine is set. This automatic feature is important in reducing the cost of labor and in eliminating the waste due to burning or imperfect welds resulting from poor judgment on the part of the operator.

Some work can be done by the resistance process that partakes of the nature of both butt welding and spot welding. Figure 24 shows the arrangement of the electrodes for making such welds. Bolts or rods can be welded to plates or tubes in this manner.

A very interesting application of spot welding is illustrated in Figure 25. It fur-

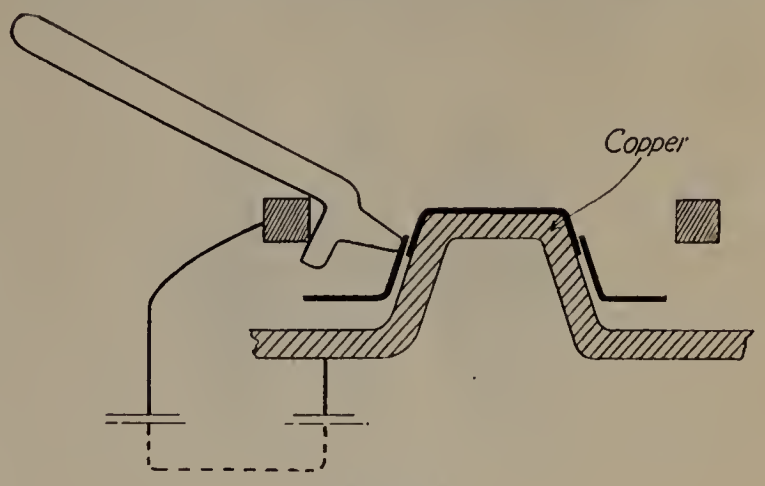


Figure 29.

nishes an economical method of lining the space between the inner and outer walls of electric locomotive bodies with felt. A large cobbler's nail is grasped in a heavy copper handle that is attached to the spot welding transformer. A push button located on the handle operates a contractor on the primary circuit, giving the operator complete control. The head of the nail is spot welded to the outer wall of the body, then the felt is applied, washers pressed over the points of the nails, and the nails bent over to hold the washer firmly in position.

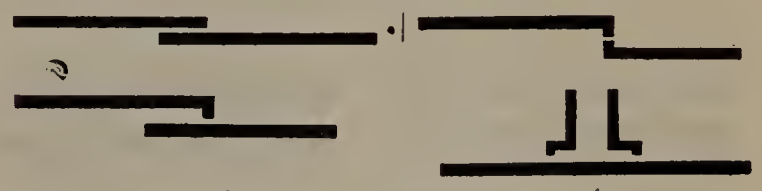


Figure 30.

Figure 26 is a sketch of one type of portable spot welder suitable for light work.

Many of the devices adopted to overcome certain difficulties in spot welding or to increase the efficiency of the machines, have become standardized in particular classes of work, and this has brought about the use of special names for some of these devices, which will be explained below.

Automatic Spot Welding. This name is applied to spot welding when the pressure

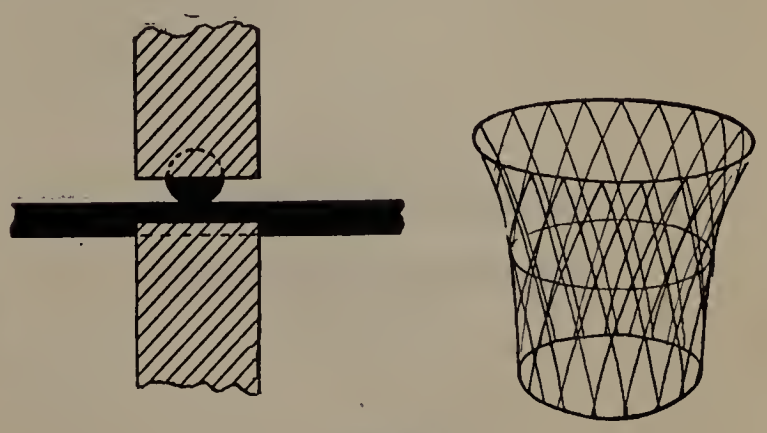


Figure 31.

is applied and the circuit made and broken all automatically.

Bridge Welding. This process is used to join thin sheets edge to edge without overlapping and without reducing the dimensions of the pieces as would be necessary in butt welding. The sheets are brought together in the proper position and then thin strips

or discs are spot welded across the joint. Figure 27 shows the appearance of the finished weld and correct and incorrect methods of doing the work. A weld can be made with the bridge having projections as shown out will be much weaker than one made with a plain flat strip or disc.

Button Welding. Where very thick work is to be spot welded it is often desirable to

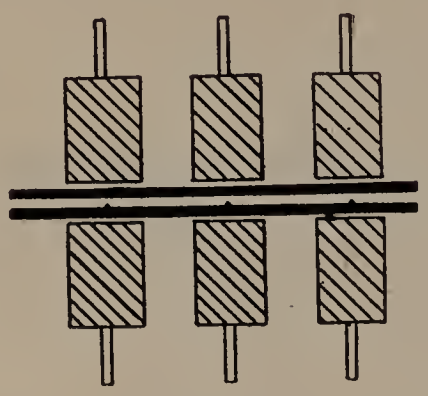


Figure 32.

find means to localize the current and cut down the amount of pressure required. Small metal buttons can be used for this purpose, one method of arranging them being shown in Figure 28. The work heats rapidly when the cross-section traversed by the current is thus reduced, and the partially melted buttons are readily forced into the joint, making a good weld.

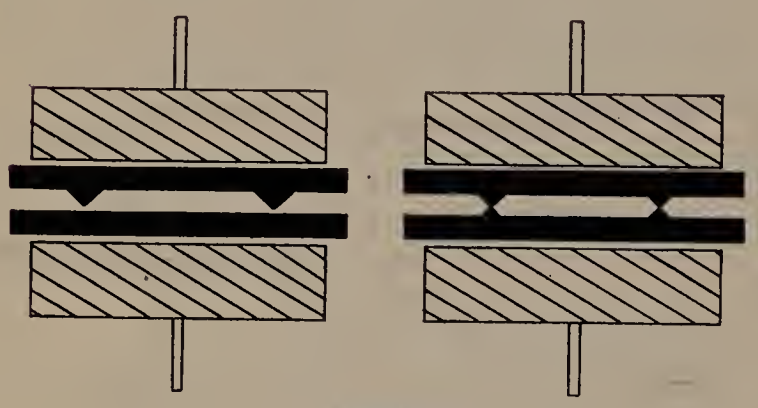


Figure 33.

Bar Welding

A system of spot welding whereby the work, consisting of pieces of sheet metal, is assembled in a jig which constitutes one terminal of the secondary circuit, while the other end of the secondary is wound around it in the form of a ridge or rail. The welding is accomplished by placing a bar of copper in the same way as an ordinary crow-

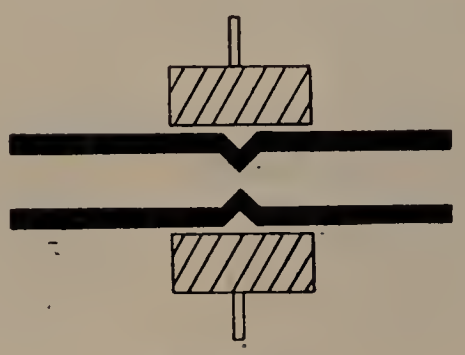


Figure 34.

bar is used, one end of the bar coming into contact with the work and the other end making contact with the rail, thus supplying the necessary heat and pressure. See Fig. 29.

Disc Depression Welding. This is somewhat similar to the button process, with the exception that in the disc depression method an annular depression is provided in one of the sheets, around the disc. The method makes possible the use of a comparatively light and portable machine for welding heavy steel plate, and also the use of less power and time for making the welds.

Duplex Spot Weld. A spot weld made by using two transformers simultaneously on opposite sides of the sheets to be welded, the currents passing through two secondaries, thus welding two spots simultaneously.

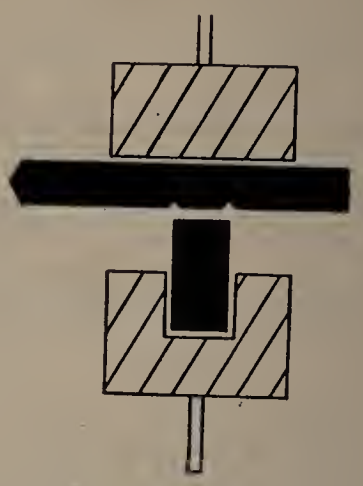


Figure 35.

Lap Welding. This is the term used when sheets or pieces are overlapped and spot welded. It is also one of the simplest jobs performed on a spot welder, and is used in this simple form mostly for work on thin sheet stock. Two methods of arranging the sheets have been shown already in Figure 23, and Figure 30 gives a few more common methods. Where thick plate is to be welded with no more preparation of the parts than is shown here a heavy machine and a lot of power and pressure will be required for the work.

Mash Welding. The term is applied to the spot welding of two wires or rods at an angle to each other, as in the manufacture of wire wastebaskets, lampshade frames, etc. Figure 31 shows how the electrodes are grooved to hold the stock.

Multiple Electrode Welding. Sometimes it is possible to save time and power by making several welds at once, in which case the spot welder is equipped with two or more electrodes. It is advisable to have the stock prepared as shown in Figure 32, the projections helping to localize the current.

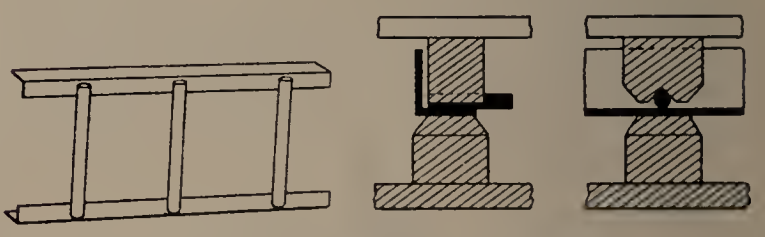


Figure 36.

A process of this sort is used in spot welding pins to sheets or plate metal. Successful multiple welding really requires a separate transformer for each weld.

Multiple Point Welding. Instead of using a series of electrodes as in the preceding case, it is simpler to have the work prepared with a series of projections and use electrodes long enough to cover several of them at once. Figure 33 illustrates the electrodes, and the preparation of the work for two simple cases of multiple point welding.

Point Welding. The metal to be welded is provided with points, or projections, and when the weld is to be made the points are brought in line with each other as in Figure 34. This has the effect of providing a

smaller contact point between the metals, which increases the resistance and allows the weld to be made with the consumption of less time and power. The process is also called **Projection Welding.**

Ridge Welding. This is the same as point welding except that instead of a single point

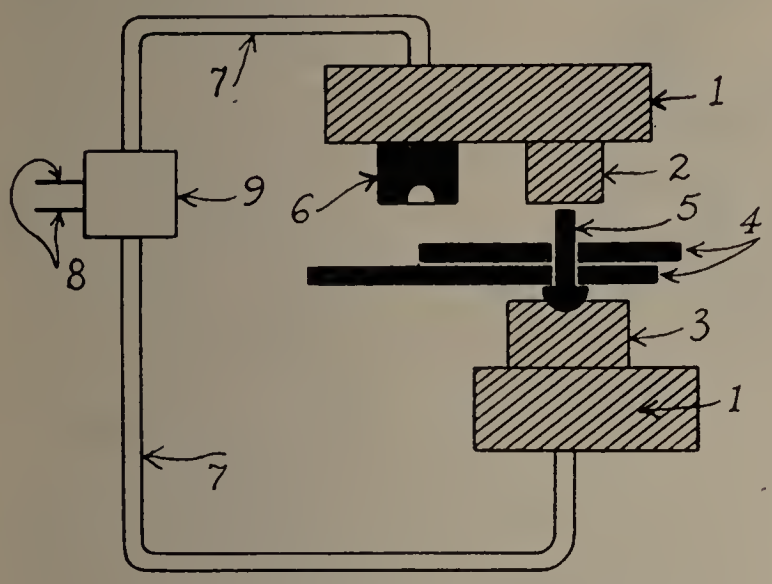


Figure 37.

1, Lower Electrode Holder; 2, Upper Electrode; 3, Lower Electrode; 4, Work; 5, Rivet; 6, Steel Die; 7, Secondary; 8, Primary Leads; 9, Transformer.

a ridge is raised in the metals in such a way that the ridges on the two pieces come together in the form of a cross.

Seam Welding. See section on **Line Welding.** Both terms are applied to the same process.

Tee Welding. When two pieces are to be welded in the form of a "T" as in Figure 35 the process is a combination of butt and spot welding, one of the pieces being held in a hollow electrode or copper clamp, and the other resting against an electrode as in spot welding. The diagram at the right in Figure 23 shows another arrangement. It should be noticed that one of the pieces in Figure 35 has been milled to form a sort of projection for localizing the current.

Also called "T Spot Weld"

Tie Welding. Same as **Bridge Welding.**

Combinations of all the above processes have been made for special jobs. In fact nearly all resistance welding machines are limited in their application to the work for which they were constructed. Sometimes it is only necessary, however, to make a change in the construction of the electrodes to make a machine do work of varied character. For example, Figure 36 shows how rods or tubes can be spot welded to angle irons to make ladders or gratings. Here it has not been necessary to groove both electrodes, as in mash welding.

It has been demonstrated in practise that spot welding is in every way superior to riveting wherever it is at all possible to use a spot welding machine, and research work is being done to apply it more extensively to shipbuilding to supplant riveting as far as possible. But riveting can also be done with a spot welder to heat the rivets, and has proven economical and efficient. One difficulty that was met at first was the hard wear on the electrodes of the spot welder in mashing the heads of the rivets. This has been overcome by using a copper electrode to heat the rivet and then switching to a steel die to upset it. Figure 37 shows the essential features of such a combination. Figure 38 shows the position of a rivet in a simpler method of riveting with a spot welder and also the use of a rivet placed between the sheets and tapered for both holes.

The advantages claimed for the spot welding process are: it is not difficult to make a joint that is stronger than the pieces themselves; there is a big saving in time, both in the operation itself and in the preparation of the work; the joint is not affected by the subsequent application of high temperature; the operation is clean and quiet; the current is used only while the weld is being made; and no flux is necessary because there is no danger of oxidizing the material in this process.

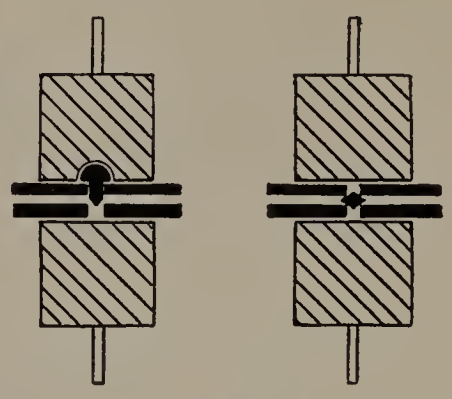


Figure 38.

Maintenance of Spot Welding Machinery

Spot welders will not work at their best unless proper provision is made for regular inspection and care. It is especially important that all electrical connections be kept clean and tight at all times. Always look for a loose connection when there seems to be a loss in heating efficiency. When the operation appears to be sluggish otherwise, a general cleaning and oiling of moving parts will often prove to be all that is necessary. Cleanliness is particularly necessary at the welding points of the dies. The lower die is under the observation of the operator constantly, but the upper one may have become soiled and be the cause of slow heating, so it should be inspected immediately at the first sign of trouble. In case there seems to be too much heat, the trouble may be with the water cooling system, if the electrodes are water cooled. It does not take long to disassemble and clean out the entire cooling device at regular intervals, and it helps to keep the machine in perfect condition.

Mention has already been made of the desirability of cleaning all rust, scale, or dirt from the surfaces to be welded. Clean stock means a weld free from slag inclusions or gas pockets and a weld made with the exact amount of heat which the transformer is intended to supply. It also means a minimum amount of wear on the electrode points, and consequently a minimum amount of electrode replacement.

To save unnecessary wear on the equipment it is advisable to instruct operators as carefully as possible in the principles of resistance welding, so as to prevent them from getting the idea that difficulties can be overcome by yanking the lever. They need only exert pressure enough at first to get the metal at the welding temperature, then shut off the current and make the weld by exerting full pressure. If enough heat has not been supplied, extra exertion will not produce a good weld. Equally important are the precautions against attempting to let the electricity do all the work, and not supplying pressure enough. This results in burned welds and rapid deterioration of the electrodes. In all cases the manufacturer's instructions for current adjustment, welding time, etc., for different thicknesses of metal, should be followed to the letter.

OXY-ACETYLENE WELDING

OXY-ACETYLENE welds are accomplished by using a torch (or blowpipe) flame to heat the metal to be joined to the melting point. Usually some new metal is added from a filler rod which is melted at the same time and flowed together with the fused metal of the two edges of the joint. A high temperature flame (6300 deg. F) is produced at the tip of the torch by the combustion of acetylene gas with oxygen gas. Oxygen is supplied compressed in cylinders, and acetylene is taken either directly from a generator or from cylinders. Between the gas supply and the torch each gas has to pass through a regulating valve which serves to reduce the pressure to that desired for welding and to hold it uniformly at that pressure. The reader should consult the definitions of Oxygen, Acetylene, Carbide, Generators, Torch Classification, Regulators, Cylinders, and Welding Rods and Wire, in the Dictionary Section.

To get the apparatus in working order, the regulators are first attached to their respective cylinders, and then the torch connected to the regulators by suitable lengths of hose. Oxygen cylinders should be "cracked" or in other words, the cylinder valve should be loosened in order to blow out any dust or dirt which might have been lodged in the nipple. This should be done with oxygen cylinders just before adjusting the regulators. As a general rule, the threads on the valves of oxygen and dissolved acetylene cylinders are different, but the proper regulators may be recognized by the high pressure gauges. Regulators should turn up close to the valve without the use of washers.

It should be remembered that the oxygen is under a high pressure, but if properly handled, it is harmless. The oxygen should be turned on from the cylinder, the valve being opened very slowly.

Stand behind the cylinder, with the spring tension of the regulator off and the valve on the welding torch open. If there is a shut-off valve on the torch, it should also be open.

Care should be taken to see that the regulators are tight on the tank and also that hose connections are tight. Also see that all connections are free of oil, grease or dust. Use a wrench to tighten these connections.

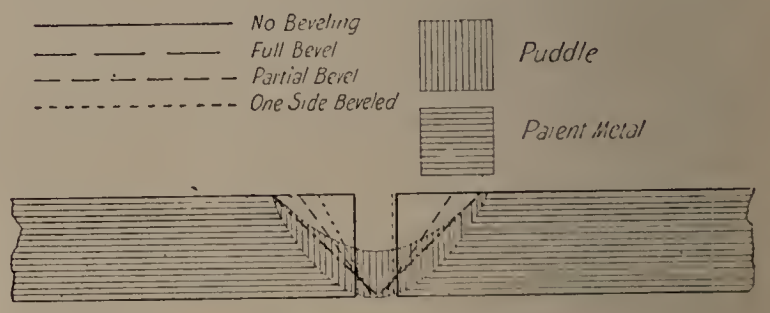
In setting up a new outfit, the hose should be blown out. Do this with oxygen, turning in the regulator adjusting screws just enough to permit the gas to flow through with some force. Very little gas is required for this. If acetylene is used for this purpose, very little should be used, especially in closed places. Torches should also be blown out. Oxygen should be used. Insert the hose in the torch head, with the needle valves open, and the flow of gas will clean the interior. Pressures are adjusted by means of the regulators and the acetylene gas turned on and lighted. The pure acetylene flame is long and bushy in appearance, getting shorter and more violent when the oxygen needle valve on the torch is opened.

As more oxygen is turned on a sharply pointed white flame is seen near the tip of the torch. This is known as a carbonizing flame, because all the carbon present in the acetylene is not being consumed. Increasing the oxygen flow reduces the sharp white flame to a small white cone. This is called the "neutral" flame, and is the flame most used for welding. A surplus of oxygen will cause the little white cone to shorten and be less clearly defined. This is the oxidizing flame, almost never used for welding purposes because the surplus oxygen burns the metal. See "Carbonizing Flame," "Neutral Flame," "Oxidizing Flame," and color chart of these three flames.

Parts are prepared for welding by beveling (See "Beveling" in Dictionary Section) along the edges to be joined so as to give the flame a chance to penetrate to the bottom of the line of weld throughout its length. If no beveling is done a considerable separation between the edges is necessary to insure penetration. The accompanying diagram indicates how the distance between the edges is decreased as the angle of bevel is increased. Before any metal is added from the filler rod the sides of the bevel are melted and run together, forming a "puddle" at the bottom of the V. The filler rod is then heated and introduced into the puddle so that the heat of the molten metal melts the rod and causes it to flow together with the parent metal.

Torch Manipulation

Some torch manipulation and movement



Beveling Plates for Welding

It is a common practice, as shown by this diagram, to increase the separation of the plates as the amount of beveling is decreased. The drawing also shows the danger of getting incomplete penetration when no beveling at all is done. When thorough penetration is not secured the weld will not stand bending and tensile stresses nearly as well as it should.

of the welding rod in certain relation are absolutely necessary to success in oxy-acetylene welding. There are, however, no absolutely fixed rules for securing sound work. The torch may be actively manipulated while the welding rod is moved but little, or the welding rod may be the more active factor while the torch is held comparatively still. The result is practically the same in either case and between the two extremes is a variety of practices, one merging into the other imperceptibly. The theory of torch and welding rod manipulation is to distribute heat evenly on each side of the joint, to break down the walls and to secure thorough penetration and union of the adding material and parent metal. If the torch is active and welding rod passive the operator secures the desired result by heat action

and gas pressure rather than by rod manipulation. If, on the other hand, he works the torch comparatively little but actively operates the welding rod, penetration and elimination of oxide are accomplished mechanically as well as by heat.

One secret of success when welding steel plates having a thickness up to ⅜-inch or more is to form a large puddle. The practice of many welders is to break the side walls in advance of the puddle for a distance of 1¼-inches to 1½ inches, making sure that the metal is fused at the bottom of the vee. Then active puddling with the welding rod begins, the pool of molten metal being about ⅝-inch wide and ¾-inch long. The torch is whipped off the puddle from time to time. This causes the metal to "freeze" on the surface in semi-circular ridges.

To obtain the best results the following points must be observed:

The line of weld on the parent metal must be heated to the proper melting point.

The added material must be heated to the same melting point to prepare it for proper fusion with the melted metal of the work.

Added material must be added continuously at as nearly a constant rate as possible.

The melted portions of the added material and of the parent metal must be puddled together by proper manipulation of the torch and welding rod.

The puddle must be protected as much as possible from the air by the envelope of the welding flame.

The welding must include not only the center of the welding line but also a certain portion of the metal on both sides.

There must not be any reheating of the molten metal after it has had a chance to solidify, if this can be avoided.

Separate adjustments must be made to suit all different conditions.

Training Welders

Naturally, a trade like oxy-acetylene welding in which so much depends on the personal education has drawn attention to the need of training men to produce sound work. There are several methods of training raw labor to manipulate the welding torch. No doubt the best method is that which expounds principles and enforces practice in approved torch manipulation. Testing the welds is also a prime requisite in a training course. If a learner sees the inside of a defective weld made by himself, which looks fair on the outside, his conceit is taken down a bit. He learns rather painfully what to avoid. Manufacturing concerns must follow methods depending on the size of shop and class of work, however.

One concern starts off a learner with a cutting torch. The man is carefully instructed in its construction and manipulation—how to turn on the gases, light and adjust for the preheating flame and to turn on the cutting oxygen when the igniting temperature has been reached. After that he is allowed to play with the apparatus for a day or two when he is given some simple designs to cut out of sheet metal. When these have been successfully mastered he is given simple blueprints and told to cut out the designs, making his own measurements. This means training in other matters than cutting, and the new men soon acquire facility in the use of tools and acquaintance with shop practice, all of which has bearing on their success as welders.

After using the cutting torch for two or three weeks the men who have demonstrated that they have the qualities necessary for good welders are given welding torches and started at work on non-pressure apparatus, water tanks, and on water headers subjected to little pressure. From this work they graduate to ammonia apparatus. It is truly surprising how quickly some men master the principles of sound welding and become competent to do the most exacting work on high pressure ammonia parts. It is needless to say that anyone acquainted with oxy-acetyelene welding will readily see that in such apparatus we have the highest and most exacting requirements. An advantage of this method of training welders is that each welder becomes familiar with the use of the cutting torch and uses it as an auxiliary tool to facilitate his work.

For instance, when making receivers or accumulators from standard lengths of lap-welded pipes, it may be necessary to cut a length of pipe into three or four pieces. This can be done in a well-equipped shop to advantage on a pipe machine, the bevelling being done at the same time. But in a smaller shop not so well equipped the cutting torch is used for cutting the pipe into lengths, having first marked the cut layout with chalk. The pipe resting on vee roller rests is slowly turned while the cut proceeds. When the welder has cut his pipe into sections he is ready then to weld on the heads and to cut the openings for nozzles, nipples and other connections. This work is done in proper sequence, the result being that the welder practically handles the entire proposition from the time the pipe comes into the shop until it leaves him to go to the testing station.

In a paper read before the International Acetylene Association, Mr. J. R. Dawson gave the following general considerations which will be helpful in the selection of filler material for oxy-acetylene welding:

Selection of Welding Rods*

Unfortunately, the practice has too often been to fill a steel weld with whatever steel rod happened to be at hand, or to weld copper with a plain copper wire, the general character of the metal in each instance determining the most convenient filler at hand, without reference to scientific balance of component elements. The results of such methods have frequently been disappointing.

A better procedure is to use a rod that will produce a joint as good as or better than the original or base metal. In this connection it is well to bear in mind that the metals joined are usually in the rolled or forged condition, while the metal deposited from the welding rod is in the cast condition. Very often a metal is of such composition as to possess excellent properties after forging and heat treatment, but in the form of the casting is of little value.

In order to obtain a high grade weld it is necessary to fuse the edges of the base metal and the welding rod at the same time, and to obtain an intermingling of the two metals. The product of this mixing may be entirely different from either of the original metals. This may be illustrated by attempts that have been made to weld cast iron with steel rods. The mixture of the metals at the junction is weak, brittle, hard to machine, and lacking in the good qualities of either steel or cast iron. However, when the product is not required to stand severe strains or shocks there are certain instances when steel may be welded to cast iron.

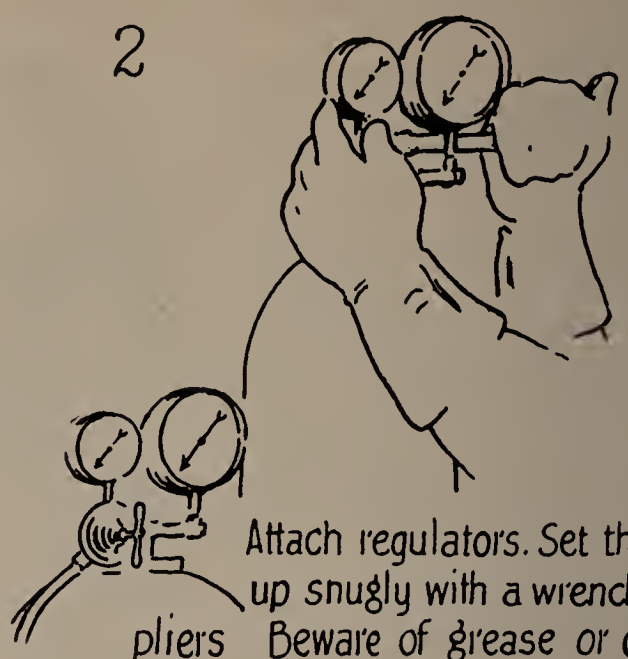
The composition of the rod should be such that during welding the metal is not so liquid as to run easily over the unfused metal, covering up improperly fused and oxidized surfaces, nor should the melted metal be so viscous as to pile up and cause difficulty in obtaining a weld that is homogenous and smooth at the surface. A satisfactory rod will be sufficiently free from impurities and of such composition that the slag formed by welding will fuse and float readily to the surface of the molten pool. A very thin slag has the advantage of protecting the metal surfaces from oxidation,

**For American Welding Society specifications for welding rods and chart of welding rod sizes, see under "Welding Rods and Wires," in Dictionary Section.*

1

"Crack" Oxygen cylinder valves - this blows out all dust which may be present

2



Attach regulators. Set the nuts up snugly with a wrench, not pliers Beware of grease or oil

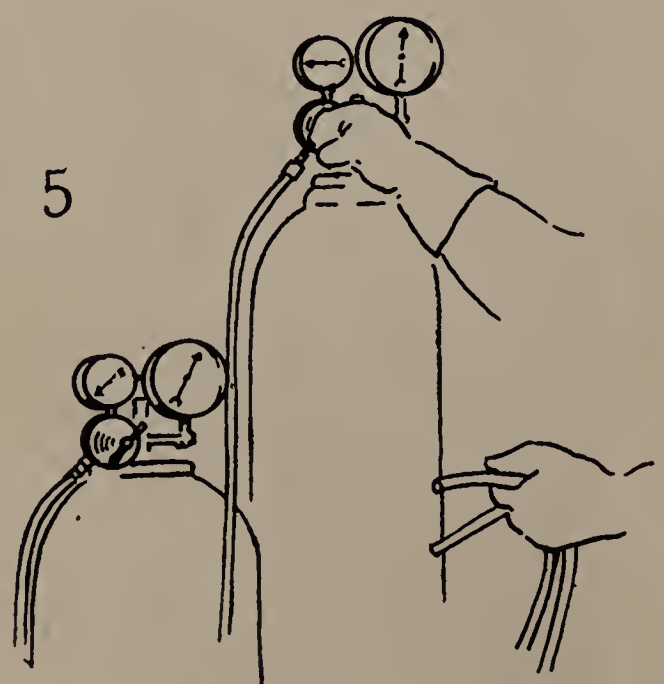
3

Attach hose to regulators. Be sure all connections are clean and gas tight.

4

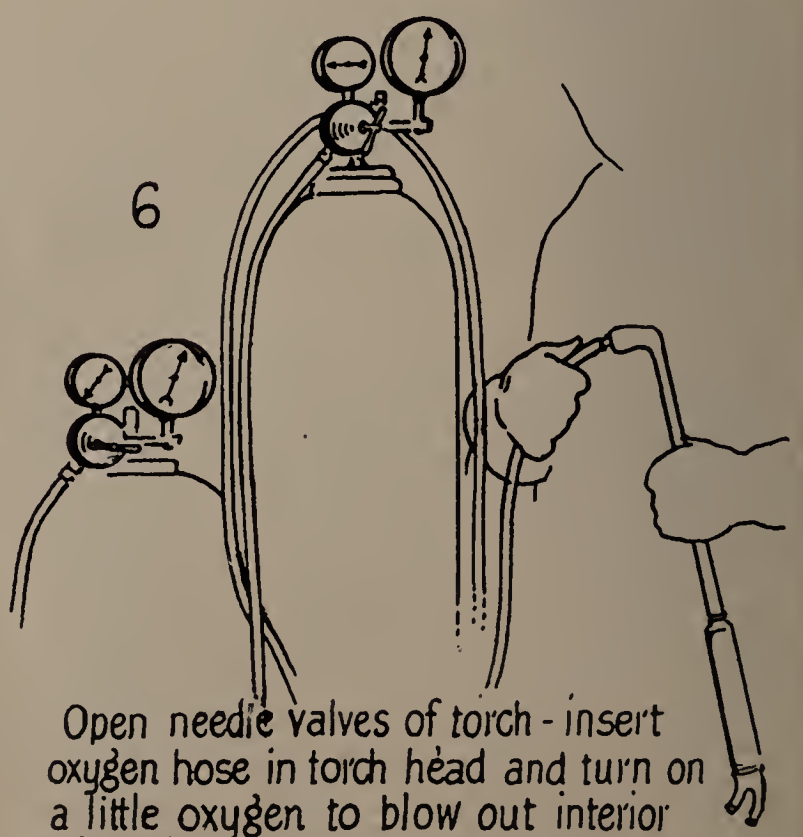
Release regulator adjusting screws and open cylinder valves carefully.

5



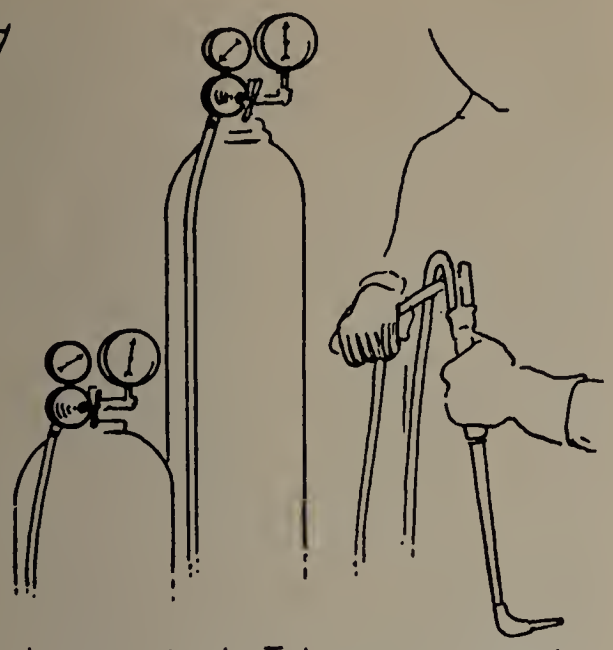
Turn on just enough gas to blow out hose.

6



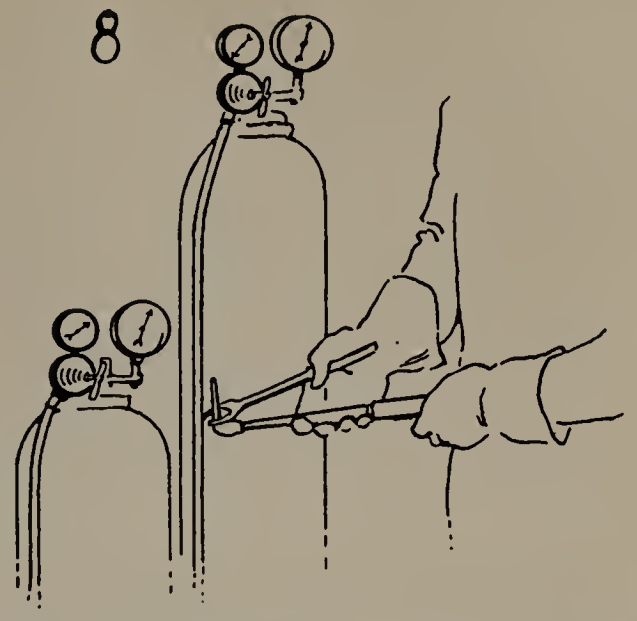
Open needle valves of torch - insert oxygen hose in torch head and turn on a little oxygen to blow out interior of torch.

7



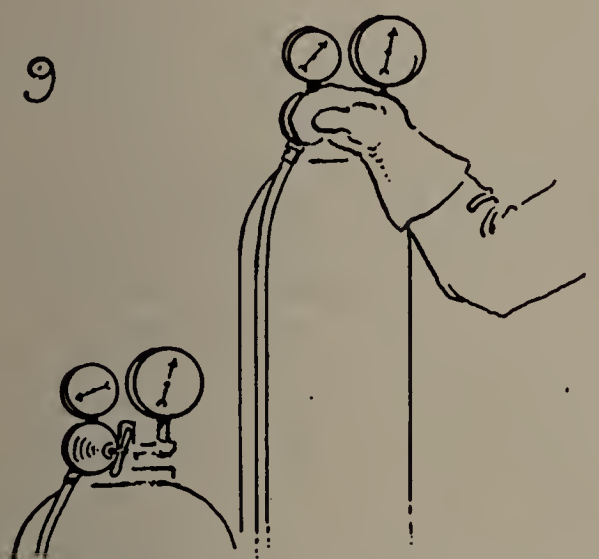
Connect hose to torch. Take care to attach oxygen hose to oxygen inlet on torch. Make connections clean and gas tight.

8



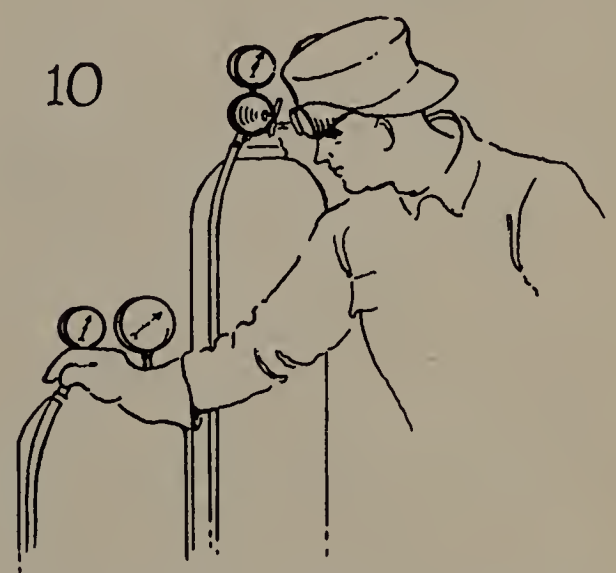
Insert tip in torch head and tighten with wrench Be sure the tip is clean. Use just enough pressure to make tip gas tight. Consult Manufacturers' Chart when selecting tip.

9



Open needle valves of torch and turn oxygen regulator adjusting screw until desired working pressure is indicated, then close oxygen needle valve.

10

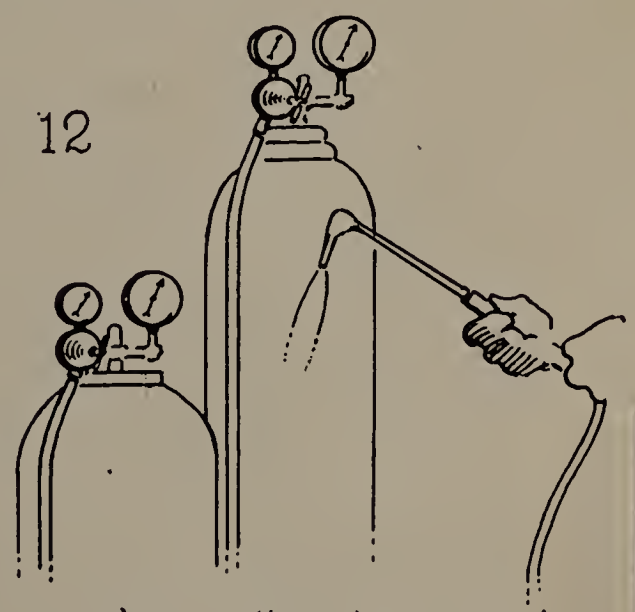


Open acetylene needle valve and turn regulator adjusting screw until desired acetylene pressure is obtained.

11

Ignite acetylene with torch lighter - avoid use of matches or open flame.

12



Open oxygen needle valve and adjust for neutral. (*See Color Chart of flames*)

and when present in small amount is not readily entrapped in the weld.

Manipulation is easier and attended with greater success when the melting points of the rod and the metal being welded are approximately the same. Where there is considerable difference the low-melting-point overheated and damaged before the higher-melting-point metal is fused.

This rate of fusion also makes important the exercise of care in choosing the size of rod and welding head for a given weld. The heat supplied should be sufficient to keep a small pool of molten metal in the weld and to melt in additional metal from the rod. If the rod is too large it will tend to chill the molten bath and may sufficiently lower the temperature to retard or virtually stop fusion of the rod metal into the weld. On the other hand, if the rod is too small it will not absorb the heat of the flame and pool rapidly enough, and the excess heat which results in the weld will burn the metal.

The usual method of manipulation is to melt a small pool of the base metal and then insert the rod in the molten pool. By this method the rod absorbs the heat necessary to melt it down and at the same time prevents the temperature of the molten pool from rising far above its melting point. The principle is the same that governs the temperature of water containing ice: It cannot be heated to a temperature higher than that of melting ice until the last of the ice is melted.

The torch is gradually moved along the weld and all slag is floated to the surface and laps or cold shuts melted out, the rod being kept constantly in the pool to supply metal for filling. Care is always exercised in manipulating the rod to avoid pushing the fused metal over the unfused metal.

The covering of unfused surfaces would produce the difficulty commonly called lamination, which is similar to the seams that sometimes occur in the rolling or forging of steel. This method of holding the rod suspended in the molten pool aids in the production of a clean weld, because it keeps the melting metal covered by the pool, prevents any oxidation below the surface, and makes it improbable that any oxidation or foreign matter will be carried to the interior of the weld. Furthermore, the neutral gases when directed at the weld adjacent to the rod, envelope both the rod and the bath in such a manner as to exclude atmospheric oxygen from the weld, so that excessive oxidation cannot occur when the filling rod and the blowpipe are properly manipulated.

Since the selection of the rod depends on the service requirements of the finished weld, it may be well to consider briefly a few of the better known rods and the conditions under which they may be used to the best advantage.

The most important of the welding rods, if we judge by the quantity consumed, is Norway iron which, though really a steel, approaches closely to pure iron. A weld made properly with this rod will have a tensile strength of over 50,000 pounds per square inch and an elongation of from 25 to 30 per cent in two inches, thus combining high strength and excellent ductility.

The next in importance is the mild steel rod which contains 0.2 per cent carbon, and other elements in the usual percentage. Norway iron and this material may be used interchangeably, depending largely on the operator's preference. The mild steel rod ordinarily gives a weld of higher tensile strength but of slightly lower ductility.

High carbon welding rods are employed for building up worn shafting and for many other common uses where metal is required of sufficient hardness to resist wear and tough enough to resist shocks and other stresses. The carbon content of these rods may vary over a rather wide range, depending on the requirements of the finished welds.

Steel that has been subjected to mechanical work as in rolling or forging is strengthened by increasing the carbon content, but an increase of carbon in steel welding rods does not greatly increase the tensile strength of the resulting weld. This is due to the fact that the weld is essentially a casting and the weld metal forms in larger and weaker grains as the carbon content is increased, and to the added fact that welders have greater difficulty in obtaining sound welds with the higher carbon steels.

There are a few very skillful welders who have obtained excellent success with nickel steel welding rods containing 0.20 to 0.25 per cent carbon and 3.0 to 3.50 per cent nickel. Many other welders obtain poor results with this steel owing to cracks that form in a weld while it is red hot. The tendency to crack is due to the well known brittleness of nickel steel at high temperature. This property is illustrated by the difficulties so frequently encountered in forging nickel steel and by high temperature tensile tests showing that nickel steels as compared with other steels decrease rapidly in ductility at high temperatures.

Operators who are sufficiently skilled in handling nickel steel rods can make welds having a tensile strength as high as 60,000 pounds per square inch. This strength is greater than that of low carbon steel plate, such as boiler plate for example, and when tensile tests are made the break does not occur in the weld but generally several inches away in the plate metal.

High speed steel rods are rather widely used for making tipped tools.[1] The high speed steel is melted into a slot cut from the end of a low carbon steel shank. After correct heat treatment the cutting qualities of the high speed steel deposited by the oxy-acetylene welder are as good as the high grade commercial brands of high speed steel. The melting causes very little change in the chemical composition, usually a slight reduction of the contained silicon and manganese, so the rods used should have about the same composition as a standard high speed steel. By using this process a heavy tool can be made up of inexpensive mild steel shank, and the small tip only of high speed steel. A wide variety of shapes and sizes of tools are thus made available without tying up an appreciable amount of money in costly material, as is the case when solid high speed steel is used. The requisite for success here as with every high speed steel is correct heat treatment.

Manganese rods[2], are employed in the repair of machinery used for grinding and for other service where great resistance to abrasion is required. As previously explained, the manganese content of the rod should not be less than 14.0 per cent.

Special precautions are necessary in welding this steel. The part to be welded should be supported so that the heated portion will be under as little strain as possible; it should be preheated to redness before the welding is begun and kept red hot during the operation. In this steel the favorable properties of great resistance to shock and abrasion are brought out by quenching in water from a temperature of about 1,800° F. In order to obtain the best results after welding, the quenching practice employed in manufacture should be closely followed.

One of the commonest of oxy-acetylene welding operations is the welding of cast iron. The expenditure of a few dollars for welding in this field may easily result in the salvage of a casting worth several hundred dollars. The composition of the

[1] *See "High Speed Steel" in Dictionary Section.*
[2] *See "Manganese Steel," in Dictionary Section.*

rods used for this work is that of ordinary grey cast iron, the silicon content of which should be relatively high and the percentage of sulphur low. Excepting for certain special uses, grey cast iron is standard. Increasing the silicon content reduces the amount of carbon retained in solution during cooling, resulting in the deposition of a larger portion of it in thin graphite flakes throughout the cast iron. It is this structure which gives the fracture of grey iron its characteristic appearance. Grey iron is less brittle than white iron and is readily machined, while white iron cannot be machined. When rods of correct composition are used the weld metal obtained is usually as strong as the original casting. The tensile strength of a cast iron weld is about 18,000 to 20,000 pounds per square inch and the transverse test of 1-inch square section using a 12-inch beam loaded at the center is from 2,000 to 2,5000 pounds with a deflection of 0.1 to 0.15 inches.

Rods used for filling welds in copper[3] are made of copper to which has been added a small amount of phosphorus as a deoxidizer. When red hot, copper is readily attacked by oxygen, which has a very deleterious effect on its physical properties. Phosphorus arrests the absorption of these oxides into the weld and for this reason copper should never be welded excepting with a filler rod containing phosphorus or some other suitable deoxidizer.

Very encouraging results are being obtained in the tensile strength of the welded metal. Indeed, it is felt that users of copper are not sufficiently aware of the advantages oxy-acetylene welding offers, and a great expansion of that field in the near future is confidently expected. Until recently only about 14,000 pounds per square inch tensile strength was obtained in copper welds, but improvements in rods have made possible the production of welds testing over 22,000 pounds per square inch.

Brass[4] is successfully welded, rods of the usual brass compositions being satifactory for this use. There is some loss of the zinc content—about two or three per cent escaping in the form of fumes during welding; and where much of this work is done proper ventilation should be provided to protect the workman from the poisonous vapor. A suitable flux is always used in welding on brass or bronze. The flux forms a thin slag coating over the weld, preventing oxidation and at the same time dissolving impurities and floating them to the surface of the weld.

The most popular bronze[5] welding rods are the manganese and Tobin bronzes. They are used for welding bronzes and for building up worn bronze surfaces and also for brazing, which though really a soldering operation is capable of effecting joints of great strength. A wide variety of metals may be joined by brazing. Among these metals malleable iron should be mentioned. Although welding destroys its good properties, very high efficiency results when a brazed joint is employed.

Aluminum[6] welding and soldering by the oxy-acetylene flame has a widespread use both in manufacturing and in the repair of broken parts. The welding of broken crank cases is one of the regular services offered by most up-to-date automobile repair shops. Rods of pure aluminum as well as special rods of aluminum with zinc or copper additions are widely used and have met with much success.

Tests of Rods

Even though they may be of correct chemical composition, experience has shown that some rods are unsuited for welding. Any one of the manufacturing operations of melting, casting, rolling, cold drawing, etc., may not have been correctly handled, resulting in a faulty product. It is essential that the rods be made by good manufacturing practice.

Investigation of several curious failures of welding materials has focused attention on certain factors that as yet remain somewhat obscure. Welding rods are encountered occasionally that are not satisfactory in their welding properties, even though chemical analysis of the material shows that the proportions of the elements usually specified are correct.

Purchasers of rods may protect themselves by careful inspection and tests. Each grade of material should be tagged and given a distinctive marking, and the different grades should be kept in separate places, so that the mixing of the rods will be avoided. The surfaces of the rods should be free from lime or scale or rust. Among the impurities that rods may contain are slag inclusions, oxides and dissolved gases. Slag inclusions in the rod will be deposited in the weld and only with great skill and care will be floated to the surface. One of the most objectionable impurities in the welding rod is the aluminum oxide which results from the aluminum which is added to the steel as a deoxidizer during manufacture. While, if the manufacturing practice is right, it is not necessary to use sufficient aluminum to make trouble, an excess of aluminum resulting from careless manufacture is sure to present difficulties to the welder in the form of aluminum oxide. During welding the presence of aluminum oxide causes a granular appearing refractory slag to form on the surface of the melted metal, and difficulty is encountered in preventing some inclusion of this slag in the weld.

Iron oxide is readily dissolved in low carbon steel, and when present in the rod it can never be eliminated by the welding operation. Excessive oxides in the rod render it hot short, and their presence to excess may be detected by heating the rod to a bright red and bending quickly. A properly deoxidized steel rod will not break or crack from this treatment.

When due to faulty manufacture, dissolved gases are present in the rod or plate metal, they will be evolved during the welding process, and when the metal cools it will be left in a weak porous condition. A very satisfactory test of welding rods is to place several short lengths beside each other on the welding table and fuse them together. Then from other samples of the same lot build up the metal to twice the thickness of the rods. The workability of the metal may be observed, and the volume and character of the slag and any evolution of gases can be noticed. This test specimen should be broken and the toughness and ductility as well as the appearance of the fracture noted. These observations, together with those made during welding, should enable the purchaser of rods to know rather definitely whether or not the particular kind of rod thus tested is suited to his requirements.

WELDING DIFFERENT METALS

Whenever it is required to make a weld between two different metals the general rule is to use a filler rod corresponding to the metal which has the lower melting point, and to concentrate the heat of the flame to a large degree on the other metal. Where there is a large difference in the melting points, such as in steel and copper, the metal having the lower melting point should be fused by contact with the molten metal which has the higher melting point. A variation of this procedure consists of coating

[3] *See "Oxy-Acetylene Welding of Copper."*
[4] *See "Oxy-Acetylene Welding of Brass."*
[5] *See "Oxy-Acetylene Welding of Bronze."*
[6] *See "Oxy-Acetylene Welding of Aluminum."*

the metal having the higher melting point with the second metal, and then completing the joint as in making a weld on metal having the lower temperature of melting.

THE USE AND MISUSE OF OXY-ACETYLENE EQUIPMENT*

IT is a fact that comparatively few accidents have, during the past ten years, happened to users of oxy-acetylene welding and cutting apparatus in this country. This, I know, appears to be a broad statement, but in comparison with many other industries, and by close observation of our own, I can come to no other conclusion. Newspapers have often reported explosions of gasoline stoves and brazing pots as due to acetylene, unscrupulous men have talked about explosions for want of real selling arguments, or for other reasons best known to themselves, resulting in an entirely unjust and exaggerated misunderstanding of the process. But what of exploding molasses tanks, the many and serious calamities caused by illuminating gas and by high-tension electric wires, the daily occurring automobile accidents, transmission victims, and the long list of risks in almost every mechanical and technical industry and occupation?

During the fourteen years I have devoted to the oxy-acetylene industry as a welder, instructor and manufacturer of apparatus, I have not personally seen one single oxy-acetylene welder or cutter seriously injured. While accidents have happened—and I have had occasion to investigate some of them—nearly all of those I know of have been caused by gross negligence, willful carelessness, just plain ignorance or conditions chargeable to impure gases and defective gas containers. Aside from the last two, over which the welder has but little control, it is evident to me that with reasonable judgment in the selection of apparatus and fairly intelligent use of them the risk is no greater than with almost any other mechanical equipment, especially in view of the fact that the oxy-acetylene equipment is subject to so much misuse and careless handling. Any and all accidents are, of course, undesirable, and it is particularly from this point of view that I wish to point out to the users of oxy-acetylene welding and cutting apparatus how they should be properly handled, and to call attention to working conditions which may be more or less hazardous.

Among the equipment and materials used by the oxy-acetylene welder and cutter are the following: Oxygen and acetylene cylinders, oxygen and acetylene gas generators, gas purifying and drying devices, gas storage tanks, gas lines, gas manifolds and fittings, flash back preventers, oxygen and acetylene gas pressure regulators, welding and cutting torches, hose, connectors and adapters, goggles, spectacles, aprons, shields, preheating, chipping, and grinding equipments, cranes, chainfalls, rollers, the general line of hand tools for preparing and finishing the work, and, of course, the gases, charcoal, asbestos paper and welding materials.

Oxygen and Acetylene Cylinders

The welder is so used to handling oxygen cylinders that he is quite apt to forget that they contain gas under an unusually high pressure. Ordinarily the cylinders are thrown about as if they were so many chunks of pig iron, are dumped off wagons, oftentimes top end first, stacked up on scrap and slag heaps, are oil and mud soaked or left unprotected in the open until covered with dirt and rust. The welder is not always to blame for this. The helpers, the store keepers, the freight house men, and first and last, but not least, the oxygen companies' own drivers are largely at fault. I am not making any pleas for the gas companies; it is only for the best interest of the user of oxygen, that I state, that it is nothing short of criminal to misuse the cylinders. To throw oxygen cylinders off a wagon onto a hard pavement which may result in broken cylinder valves is to take a long and unnecessary chance. A boiler maker is wary of caulking a boiler under a pressure of 200 pounds, but the very same man thinks nothing of kicking an oxygen cylinder carrying a pressure of 1,800 pounds per square inch off a 10-foot scaffold.

"Use no oil" warnings are printed on the gas companies invoices and tags, the oxygen pressure regulators are marked in the same way, pressure cards and general instructions contain the same information, but in spite of all efforts to protect the user of the gas, welders lubricate oxygen cylinder valves with oil and the cylinders are often returned to the charging stations so greasy and oil soaked that the valves have to be removed in order to clean them and the cylinders before recharging with gas. Oil must be kept away from cylinder valves, as the presence of oil may result in bursting regulators. If any lubrication of the threads on the valves is needed, use soap water.

Reasonable care must be taken when attaching a pressure regulator to the cylinder valve. Unfortunately the threaded stems on the valves sometimes vary in diameter, with the result that the regulator nut fits too tight or too loose. If the fit is too tight the result is often a frozen nut and if too loose cross threading. In either case the threads will be damaged and the cylinder valve spoiled. The regulator nut should go on fairly easy by hand up to within one or two threads so that no undue strain is put on the valve by the use of the wrench.

Both the valve stem seat and the corresponding regulator stem seat should be wiped clean. Sand and grit in any metallic seat results in unnecessary expense, leaks and losses. If a valve sticks hard or is too loose, leave it alone. To loosen packing or retaining nuts on filled gas cylinders may result in parts of the valve being blown off. It is also bad practice to use wrenches or hammers to force the hand wheel on the valve as the tap on the valve stem may easily be broken in that way.

Oxygen cylinder valves should be opened slowly. The sudden rush of oxygen under high pressure into the regulator is sure to damage it, especially if the spring pressure on the diaphragm has not been released. The gas pressure regulators and the gauges attached to them are very sensitive instruments and must be kept in good order; the easiest way to ruin them is to overstrain them. Open the cylinder valve slowly.

What has been said about the care of oxygen cylinders also applies to acetylene cylinders, only more so. While lubricating oil in presence of acetylene is harmless, it is entirely unnecessary to use oil on the cylinder valves. Acetylene cylinders are filled with a porous substance, which makes it possible to charge them with acetylene under pressure which otherwise would be prohibitive. This porous substance must, however, be uniform and one of the best ways to maintain that condition is to handle the cylinders with care.

As the acetylene is inflammable it is self-evident that the cylinder valves must be closed absolutely tight when the cylinders are not in use. Any inflammable gas allowed to escape in sufficient quantities and in a confined space is dangerous, and acetylene is in this respect no exception.

Acetylene cylinders used for welding should be kept in upright position. Some means should be provided to prevent the gas cylinders from toppling over, which generally results in broken regulators and gauges. Leather straps or iron bands serve the purpose, but the best way is to use suitable hand trucks on which the cylinders are securely fastened by means of chains or straps.

**Written for The Welding Engineer by C. J. Nyquist.*

A few years ago various types of small oxygen generators were in use. The Chlorate of Potash type was, no doubt, the most common. More modern and more economical processes for the production of oxygen from air or water are, however, now operated on such a tremendous scale, that there is no general demand or necessity for the so-called chemical oxygen generators, except in places located far away from the large oxygen producing stations. The chief objections, from the safety point of view, to the types of this class of oxygen generators with which I am familiar, is their crudeness and unreliability. Impure chemicals and carbonaceous materials such as pieces of wood. charcoal or paper mixed with the chemicals used in some of this apparatus, are apt to cause quite serious explosions.

Some of the large consumers of oxygen have installed electrolytic oxygen plants, of which there are several types manufactured in the United States. The only risk in handling properly constructed electrolytic plants is in disregarding the operating instructions issued by the manufacturer. The plants should be operated by reliable and sufficiently well instructed men, and all use of home-made "improvements" and freak devices should be discouraged. It must be understood that the construction of a reliable electrolytic plant, and for that matter almost any gas producing plant, is an engineering problem and should not be the subject of the ordinary handy man's experiments.

Perhaps the most troublesome part of all high pressure oxygen plants is the compressor. The strain on the machine, packings, charging line, piping and fittings is extremely severe. For pressures up to 2,000 pounds per sq. in. the best compressors made are none too good. And the same applies to the rest of the material that make up the compressing plant. It is the poorest kind of economy to use cheap equipment for high pressure compression; the "safety first" rule is a good one to follow and pays well in the end.

Low pressure compressing plants, practical for individual use, such as compressing oxygen direct into storage tanks at from one to three hundred pounds' pressure or for compressing gas drained from the nearly empty oxygen cylinders, are easily operated. A few feet of oxygen per cylinder is no small item in establishments using several hundred cylinders per month. Such a plant, consisting of a gas-holder, a gas storage tank, some piping and a small compressor is comparatively inexpensive and with reasonable care entirely safe to handle.

The "Use no oil" rule applies strictly to the lubricating of all oxygen compressor cylinders and pistons, as well as all other parts of the compressing plant in contact with oxygen under pressure.

The compression of acetylene is a much more serious proposition and should as a rule be left to the manufacturers of dissolved acetylene who have the proper facilities and are in position to give the process the attention and supervision it demands. Some of the U. S. Navy yards are equipped with acetylene compressing plants but they are among the exceptions and are far better able to enforce strict control than the ordinary welding or manufacturing plant. To compress free acetylene in the same manner as oxygen or air is compressed is highly dangerous and absolutely forbidden. The acetylene cylinders must strictly conform to specifications which call for a special porous filling, a definite amount of solvent and safety devices, and the volume of gas stored in the cylinders must be in proper relation to the amount of solvent present at any time and a corresponding permissible pressure applied. The responsible manufacturers of dissolved acetylene do not permit others to fill their cylinders. It is quite reasonable that they should apply and enforce this rule, otherwise the user of the gas would have no protection and the manufacturer of the gas could hardly assume any responsibility in case of accidents.

Acetylene generators are in some respects similar to steam boilers. They need a certain amount of water when in operation; they have safety valves which should be in working order; they are safe and economical in proportion to their construction, their condition, and the care they receive, and a fair amount of intelligence is required to run them.

Some time ago some one advertised a new acetylene generator construction and offered to furnish all the necessary drawings for a very small sum of money. The main part of the contraption was a kitchen boiler. To my way of thinking a kitchen boiler is about as suitable for acetylene generation as for steam generation, in other words, it is useless for both purposes. The kitchen boiler and the milk-can types belong to the so-called "tin can" varieties of acetylene generators, which in past years have caused a lot of grief and have been a detriment to the legitimate acetylene generator business.

For welding purposes only the best acetylene generators are worth having. There are several welding acetylene generators of good construction on the market, but none of them will give satisfaction unless they are handled right. It is not the fault of the generator if the lime is allowed to plug it up, if stuffing boxes leak gas, if connections are loose or if parts are missing. I have seen many orderly generator rooms but I have also seen some that are kept worse than the proverbial pig pen. A man must take pride in keeping up his machinery if he expects it to give good service, and a real acetylene generator is a gas producing machine which requires and should be entitled to both attention and upkeep.

The operating instructions which are furnished with the generators generally contain all the necessary information; the main thing is to follow them. There is nothing very complicated about most acetylene generators used for welding purposes. The principal parts of the most common types are a water tank, a carbide holder, a gas chamber, the feeding device and the safety appliances. If a man is taking care of a generator he certainly should know how to do it and know the purpose of at least every visible part of it. About the most important part of the operating instructions is that there must be a sufficient amount of water in the generator before refilling with carbide or starting the carbide feed. Generator feed constructions, which permit small water pockets in any part of the feed mechanism with which the carbide can come in contact are unsafe.

In any acetylene generator, regardless of whether the water is fed to the carbide or the carbide to the water or whether the gas is generated at a pressure of only a few ounces or up to the pressure limit of 15 lbs. per sq. in., the most essential requirement is **cool gas generation.** A hot fire and low water in a steam boiler is apt to cause serious trouble; excessive amounts of carbide and shortage of water may also prove highly undesirable. Personally, I feel sure that an impartial investigation of generator troubles would disclose the fact that most of them are due to overhead gas. Generators must not be operated beyond their capacity. To overwork them is to deliberately invite accidents and damage.

Acetylene is nearly as heavy as air and for that reason it takes a considerable time to clear the generator of gas if opened up for repairs. It is not safe to use an open flame inside the generator, no matter whether it has been left open for hours or days. It is necessary to clean the generator tank thoroughly and to fill it up to overflowing with water in order to be sure that all of the gas is disposed of. The same precau-

tion should be taken if repairs on the generator tank are made which require welding, brazing or soldering.

Gas Storage and Distribution

The storage of oxygen and the distribution of oxygen through pipelines is quite similar to air storage and distribution, except that oxygen deteriorates the lines sooner and that greater precaution must be taken to avoid losses due to leakage. If welding is what we claim for it, it is certainly advisable to weld low pressure storage tanks and the pipeline joints. Water traps in pipelines must be guarded against and the lines should be well supported in order to avoid strains on them.

It is not advisable to use large storage tanks for acetylene, at least not inside of factory. It is, of course, necessary to use acetylene gas holders and comparatively small pressure compensation tanks, but they should preferably be placed outdoors. Acetylene distributing lines must, and for obvious reasons, be made tight and kept tight, which also applies to all cocks, valves, gauge connections and water seals on the lines.

Testing for leaks should not be made with lighted matches or any kind of flames. While there might be a difference of opinion as to the risk of flame tests, especially under certain favorable conditions, it is nevertheless bad practice to use open flames for testing leaks of inflammable gas. It is quite true that pipelines filled with acetylene and even acetylene generators containing acetylene under pressure have withstood intense fire with only slight external damage. This only proves, however, that the gas in them happened to be pure, which is not always the case. Furthermore, it is not necessary to take chances when it is just as easy to test for leaks by the use of soap water. Pressure storage tanks and gas pipelines should be provided with pressure gauges, and check test made regularly to make certain that the gas distributing systems are free from leaks.

Manifolding acetylene cylinders must be limited to tubing of very small diameter. A pressure on the acetylene in the ordinary pipelines exceeding 15 pounds per square inch is not permissible, under present regulations. Oxygen cylinder high pressure manifolds are convenient and safe provided the piping, fittings and valves used are of sufficient strength to stand the full initial cylinder pressure, or in other words not less than 2,000 pounds per square inch plus a proper safety margin. It is worth while to spend the money for a real manifold, a cheap one may prove to be altogether too expensive.

Flash-back preventers in gas pipelines generally depend for their operation on water seals, and it is, consequently, obvious that the operator must see to it that the water in them is continuously kept at the proper level. Some gas welding systems require individual water sealed flash-back preventers for each welding station. These must also, of course, be kept in good working condition and possible cracks or leaks due to freezing of the water in winter time or rough handling must be repaired or the damaged water seal replaced before using the station.

Regulators and Torches

The most neglected parts of the oxy-acetylene welding and cutting equipments are generally the gas pressure regulators and the torches. Many operators entirely disregard the instructions given them regarding the use and the care of these instruments. Welding should be recognized as a trade but there certainly must be some requirements demanded of welders besides the ability to weld metals. Any welder worthy of the name should be familiar with the construction of the apparatus intrusted to his care, and should feel obliged to use them with the same care and consideration as the mechanic uses his machinery, tools and instruments. Just as easily as one can distinguish the scrub machinist from the real, dependable mechanic by the quality of his work and by the way he keeps his tools in order, so can the good welder and cutters be told from the metal melters and burners. It is a joy to find welders and cutters who take good care of their apparatus and fortunately many of them do. Any fair minded welder or cutter will, I am sure, agree with me that it is deplorable how some of this apparatus is handled. Look into some tool boxes and bench drawers, and you will find regulators, torches, tips, wrenches. spikes, bolts, nuts, scrap iron and what not all in a jumble and disorder. On the other hand the welder and cutter who actually takes his work seriously also takes a pride in having his apparatus in first class order.

The gas pressure regulators are designed to reduce the initial gas pressure to a desired working pressure and to maintain that pressure. That is certainly not done by forcing the adjusting screw against the springs and the diaphragm clear up to the thread limit and then checking the gas flow by the torch valves. The most common types of regulators have the seat holder connected to the diaphragm. When the spring pressure is applied the regulator seat is held a considerable distance away from the regulator nozzle. If then the gas is suddenly driven into the regulator the pressure against the diaphragm forces the seat violently against the nozzle and the result is often a damaged regulator seat. Unfortunately the cylinder valves in use do not provide for this condition, and it is, therefore, necessary to release the spring pressure on the regulator diaphragm before the gas pressure is admitted into the regulator and to open the cylinder valves slowly. A gas pressure regulator should be set at the desired working pressure when operating and the spring pressure on the diaphragm relieved when the cylinder pressure is shut off. Another reason why cylinder valves should be opened slowly is that the severe and sudden pressure on the gauges is apt to strain them. The regulator gauges, especially the high pressure oxygen, should be provided with safety outlets to prevent damage in case of leaking gauge springs.

Oxygen regulators must be kept free from oil, as oil in a regulator is apt to ignite under heavy oxygen pressure. Dirt, sand, metal chips or other solid matter caught between any regulator seat and nozzle often results in leaking and creeping regulators.

On the construction and condition of the welding and cutting torches depend largely the results obtained by the oxy-acetylene process. The safety of operation is even more important. It is, therefore, evident that considerable care should be given to the right selection of the torches. As the process is comparatively new and in a state of development, all of the apparatus used is subject to improvement. There is nevertheless a considerable difference between a real torch and some brass goods sold under the same name and recommended for the same purpose. The most undesirable features of some torches are, flimsy construction, their tendency to flash back, poor gas mixture, unhandiness and excessive weight. Leaky joints, tip seats and hose connections are the causes of much trouble. But even the best torches will not last long or give satisfactory service unless they are given reasonable care.

In properly designed and constructed torches the gas inlets in tips and gas mixing devices are drilled to exact sizes. Changing of these holes or bores by re-drilling or reaming invariably results in trouble. If necessary to clean them a soft wire should be used. The tips are often damaged by being either reamed too large at the outlet

or upset so that the holes become irregular or partly closed.

Torch valves should be kept in good condition and the packing nuts on the needle valves drawn up fairly tight to avoid gas leakage. Metal seated swivel hose connections are better than stationary hose nipples, but must be so designed as to give an absolutely tight seat under any pressure used. The hose must be securely fastened by wire or screw clamps to the hose connection. Shellac or rubber cement may be used to insure a leak free joint between the hose and the connection nipple, as leakage at this point results in considerable loss of gas and sometimes in bad burns.

Accessories and Working Conditions

The welders accessories, the ordinary shop tools and the welding materials do not seem to be of much consequence from the safety point of view. A number of the accidents charged against the oxy-acetylene industry are, however, due to the reckless handling of these seemingly unimportant items. A little better supervision, a little more care, a little better judgment and most of these accidents could have been avoided. Some time ago I read about a man in Johnstown, Pa., who was cutting holes in a steel plate which he rested on an oxygen cylinder carrying 1,500 lbs. pressure. He cut through the plate and also pierced the cylinder wall. The pressure blew the plate into the man's face, causing instant death. A sad accident, to be sure, but how easily avoided. Perhaps some reader of this will think that a man so ignorant as that ought to be killed. Negligence, carelessness, and ignorance are the main causes of very many accidents, and you will find men in almost every shop and factory who do things just as bad.

The welder who pokes his red hot welding rod into some one's face while adjusting his torch is guilty, and so is the man who takes chances with oil and gasoline tanks. Of course, he knows that they should be cleaned and steamed thoroughly, but that takes time and he takes a chance, perhaps, once too often.

Look after the hose fittings and the hose. It is a safe bet that loose hose connections and poor hose are profit sharing in many shops, and quite a few burns can be debited against them. This also applies to connectors and adapters which may either be poorly machined or not drawn up sufficiently tight.

The question of protection for the eyes is one of considerable concern. Some welders demand bluish-green, some amber, others cobalt blue or other colors, tints or shades, while there are welders who never did and never will use any goggles or glasses of any kind. And there are goggles galore; goggles leather rimmed, edged with silk and satin, metal bound, perforated, wire screened, leather strapped, chain connected, hinged, cupped, soft and hard, single and double lensed, round, oval and leaf shaped.

Any bright light is injurious to the eyes but there is a decided difference. Glaring at the sharp light of an electric arc for a few minutes, without proper protection for the eyes, may land one in the hospital. The oxy-acetylene flame, on the other hand, is practically free from injurious rays, and while I recommend the use of glasses and goggles for welders, I believe that there is no virtue in using very dark glasses, especially for light work. Aluminum welders seldom use glasses for the simple reason that the welding flame itself does not trouble them. The important fact to remember is that the main reason for protecting the eyes when welding is not the rays from the oxy-acetylene flame but from the molten metal. Welding on heavy steel and cast iron jobs requires quite dark lenses. There is much less strain on the eyes if lighter tints of lenses are used on light steel, copper, brass, bronze and aluminum welding. Men who are unfortunate enough to have poor eyes should not attempt to do either welding or watch repairing, as both are trades which require fairly strong eyes.

A serious condition in some repair shops is the handling of heavy work. Welders are not generally riggers, and the way some heavy parts are oftentimes unloaded, moved, turned, set up and blocked is a caution. Weak straps and shackles, slipping holds and crumbling supports are almost sure to cause accidents. The rollers used to move heavy posts are treacherous in the hands of inexperienced men; careless use of rollers often results in smashed toes and fingers. In this connection I would call attention to the use of oxygen cylinders as rollers. It is bad enough to use flat topped acetylene cylinders for scaffold supports, but to subject high pressure cylinders to crushing loads is simply outrageous.

Curly headed cold chisels and greasy hammer faces are bad actors and result in face cuts and bruised hands. Keeping the chisels well dressed, and the hammers dry, will save both time and pain. Emery wheels require the regulation protection covers, and clear glass goggles should be used when grinding to protect the eyes from particles of emery and metal.

Poorly ventilated shops and charcoal fumes do not go well together. The poisonous carbon-monoxide fumes given off from the charcoal preheating fires causes dizziness, vomiting and sometimes complete collapse. The prevention is good ventilation and long torches. Welding of galvanized materials and alloys containing zinc, require provisions for carrying off the zinc fumes. Painted, greasy or oily articles should be cleaned before welding, both for the sake of the welder's comfort, as well as for reasons of fire risk and efficiency of the welds.

The question of industrial safety is one which is now being given a great deal of attention. Federal, state and individual commissions are working faithfully to determine the causes of accidents, and to devise means whereby the risk percentage may be reduced to the lowest limit. The subject is a very large one, a very important one and one which, in the interest of our own safety, demands our individual attention. It is, however, not altogether what we do individually that counts, we necessarily must assume some responsibility for what others do, and we are, therefore, under obligation as welders, interested in the future of our industry to see to it that the working conditions in our own industry are as safe as possible. We may differ about other questions, but we can certainly agree on assisting each other in making the oxy-acetylene industry, not only one of the most interesting, but also one of the safest industries.

Common Defects in Oxy-Acetylene Welding

Failures in oxy-acetylene welds are generally due to the following mistakes in operation: Lack of penetration; adhesion; carbonizing; oxidizing.

Lack of penetration causes a weak spot at the bottom of the weld. The only way to guard against it is for the operator to take great pains to see that the fusion penetrates to the very bottom. See "Penetration."

Adhesion is caused by having molten metal flow over cold metal. It can be avoided by taking pains to melt the filler rod in the puddle, and by taking care that the molten metal is not forced ahead by the flame on to the unmolten portion of the parent metal.

Oxidizing. and carbonizing are caused by improper flame adjustment and can be avoided by taking pains to maintain a true neutral flame throughout the welding operation. See "Oxidizing Flame"; "Carbonizing Flame" and chart of Welding Flames.

OXY-ACETYLENE WELDING ALUMINUM

A WHITE metallic element. After prolonged exposure to air it has a slight violet tinge. Specific gravity cast is 2.583, rolled 2.688. Melts at 626 C. It is the third most malleable and the sixth most ductile metal. Slightly harder than tin. Not magnetic. Combines eagerly with oxygen and chlorine. Coefficient of linear expansion is .0000222. Specific heat .227. Latent heat of fusion 100 calories. Thermal conductivity

Finished Aluminum Weld.

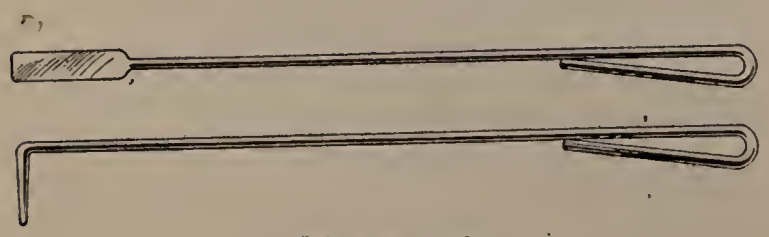
31.33. Electrical conductivity 60.5% that of copper for equal volumes, or double that of copper for equal weights.

	Elastic limit, tons per sq. in.	Ultimate strength tons per sq. in.	Reduction of area per cent.
Cast	3	7	15
Sheet	5½	11	35
Bars	6½	12	40
Wire	7-13	13-29	60

The use of aluminum is wide, welders encountering this metal frequently, particularly in automobile construction, where it is used in the construction of crank and transmission cases, pistons, body, etc. Except for body work it is rarely used in the pure state, but is usually found alloyed with other metals, such as copper, tin, magnesium or sometimes zinc.

Aluminum possesses a melting point about half that of cast iron and conducts heat three times as fast. The shrinkage of aluminum is also greater than cast iron and it will also cool from a molten state to a smaller space than cast iron.

To weld aluminum a tip as large as that used for cast iron of the same thickness should be used. Because of the rapid conductivity of heat a large area surrounding the weld is hot and therefore expanded, hence the necessity for guarding against warpage and expansion and contraction strains. Two general systems of welding aluminum are used. For the "Puddling" system paddles are used about as shown. The pointed rod is used to scrape out the weld and the flat rod is used for "patting" or working the added metal into the weld. In this system the metal is brought to the point where it is plastic, care being used not to have it too fluid, and it is worked very much as a baker works dough. The oxide



Puddling Sticks.

of aluminum forms on the surface of the weld, in the form of a scum, which is scraped off with the paddle. As a new surface is exposed oxide immediately begins to form, so care should be used to have the welding rod plunged into the molten metal when adding metal to the weld, to avoid excessive oxidation. A neutral flame is used.

The "Flux" system involves the use of a suitable aluminum flux and the metal is handled practically as is cast iron. Flux is added to the weld with the welding rod, in sufficient quantities to destroy the oxide. As the flux is added to the weld the dull gray color disappears and the metal assumes the appearance of bright silver, becoming dull as more oxide forms. Dirt, grease and foreign matter in the line of the weld may be removed by bringing the metal to a melting point and scraping the old metal out with the welding rod.

For repair work the puddling system is in wide use. When properly executed such welds require less finishing than a flux weld, although puddled welds require more time, due to the necessity of removing the flame from the welding line while the metal is scraped and puddled. It is more difficult to learn to weld aluminum by the puddling process and the strength of the weld is not as great as a properly executed flux weld.

Annealing welded aluminum castings is often advisable, for the purpose of preserving the form without setting up strains. Packing the casting in dry soft wood sawdust is commonly recommended for this. In the case of sheets, they can be placed between dry pine boards, which serve the purpose of holding in the heat.

Aluminum welding rods most commonly used in repair shops are alloys of about 93% aluminum and 7% copper. These rods are cast. Drawn or rolled rods are too ductile, bending easily and not mixing readily with the weld.

Many shops cast their rods, old cases, etc., being saved for this purpose. There are many objections to this practice, however, and it is not recommended.

WELDING STEEL

THE importance of the proper adjustment of the flame in welding steel cannot be too strongly emphasized. Always use the correct flame. Many beginners believe steel to be one of the easiest metals to weld successfully, but steel is the most difficult to master. A passable weld can be made by a new operator, as there is usually an opportunity to build up the weld, making it thicker than the original strength, but the fact that the piece will hold is not due to good welding.

At best a steel weld is nothing more nor less than cast steel, without the grain and fiber produced by hammering or rolling, and consequently its tensile strength and ductility are usually below that of rolled or drawn steel. Even in the best weld then, we do not obtain 100% of the original strength and ductility, with the exception of very low grade steels or perhaps steel castings, and a poor weld shows perhaps only 50% of the original strength.

There are several important rules to observe, among which are the following:

Use the correct flame.

Weld with the non-luminous mantel just touching the metal.

Melt the steel only once or as little as possible.

Keep it in a molten state as short a time as possible.

Hold the filler rod in contact with the weld while adding metal.

Heat the metal only enough to weld it: more heat is a detriment to the weld and an absolute waste.

If these suggestions are followed a good weld is likely to result.

A great many welders, especially those who learned the art in the earlier days, are prone to swing the flame in a circular or semicircular path, especially while making a large weld in a cracked sheet or a tank seam. The better method is to hold the flame comparatively quiet and work the filler rod. Swinging the flame on and off

molten steel necessarily allows the oxygen of the air to come in contact with it and it results in a certain amount of detrimental oxidation. It is just as easy to learn to move the rod instead of the flame and the results are generally better. On small work the molten metal would not be exposed to the action of the air enough by the swinging of the flame to be of any consequence.

Do not allow the flame to blow the molten pool of steel over on adjoining metal that is not melting. To do so will cause seams in the weld. Adjust the gases to get a soft mild flame, not a blast. A large tip and a mild flame with gases at low pressure will produce better results than a small tip and a harsh blowing flame with gases at high pressure.

A good weld in steel will be found to be as soft as the original piece but stiffer. The ductility is lowered but its ability to withstand severe strain is greater than the unwelded portion which will usually give way first.

In etching a steel weld to determine its quality, the piece is cut through the weld and polished to a high degree. To polish the surface to be etched, smooth the surface with a file or emery cloth and finish it on a polishing wheel if possible. If a polishing wheel is not at hand, good results may be obtained by using very fine emery cloth. When polishing is completed, paint the surface with the following solution: Water 75%, potassium iodine 15% and iodine 10%. A few moments will usually show results after which the piece is thoroughly washed. If the sample is to be retained for future reference, it should be thoroughly dried and coated with a colorless varnish. See "Etching," and "Steel, Structure and Restoration of."

WELDING CAST IRON

CAST iron, the easiest of all of the commercial metals to weld autogenously, was at one time considered the hardest metal to weld. In fact, as late as 1918 many welders considered it practically impossible to successfully weld cast iron without leaving the weld hard, brittle and hard to machine. As a matter of fact, however, the line of the weld in a casting should be fully as good, and probably better, than the metal in the original casting. The added metal is cast, as all welded or added metal is, and as the original metal was also cast there is no reason why, if the proper precautions are followed, the weld should not be successful. One of the most common faults with cast iron welds is that the added metal is hard, flinty, and hard to machine. For a better understanding of this fault see "Cast Iron—Hard Spots In." With a high grade adding material, correct torch manipulation and intelligent after-cooling, or slow-cooling, good welds will result.

We have, commercially speaking, two types of casting to be considered from the welders' standpoint. **White** cast iron is encountered more infrequently than **Grey** cast iron. Carbon is the element which we have to contend with, and it may be either combined with the iron, dissolved in the whole mass, or it may be present in the free state in the form of molecules of graphite.

When carbon is dissolved or combined the result is very hard cast iron, hard to work with the flame and known commercially as **white** cast iron. When carbon is present in the form of graphite molecules it is pliable, easy to manipulate and known commercially as **Grey** cast iron.

No matter whether it be a **White** or **Grey** casting, the added metal or the welding line should be of **Grey Iron.** To this end a suitable rod should be selected and attention should be given to torch manipulation and proper cooling when the weld has been completed. If the weld is allowed to cool rapidly, or is subjected to drafts, a hard and practically unmachinable surface will be the result—**White** cast iron in fact. When the weld is finished reheating and slow cooling has the opposite effect. The free carbon present is precipitated and we have a soft, easy machinable weld.

In former times it was in order to inform welders that silicon, for instance, when added to the weld and alloyed with the iron in the casting had the effect of increasing the graphite content, thus causing **Grey** iron. On the other hand, manganese, when added to the casting, encouraged a formation of **White** iron. These statements, while true, need cause the welder no uneasiness, as American manufacturers of cast iron welding rods are today well informed on this subject and are prepared to supply the proper rod for all classes of cast iron welding.

White cast iron melts at a temperature of from 1922 to 2075 degrees F., and **Grey** cast iron melts at a temperature of from 2228 to 2786 degrees F.

To successfully weld cast iron the following suggestions will be found helpful.

First: The Preparation of the Weld.

Fifty per cent of a successful weld depends on the preparation of the weld and the selection of a suitable filler rod. When the parts to be welded are over ¼ inch in thickness it is always advisable to chamfer the line of weld at an angle of about 45 degrees.[1] This is usually done with pneumatic hammer and chisels, provided the part to be welded will withstand the vibration. A skilled operator will often burn out, or V, his line of weld. This practice is all right if care is taken that the flame used for chamfering is positively neutral. Too many operators will endeavor to hasten the operation of chamfering by using a flame with an excess of oxygen. This is very injurious as it forms slag in the line of weld which will afterwards have to be floated out of the weld. So great care should be taken that the flame is neutral when burning out the V. An advantage gained, if the flame is neutral, in burning out the line of weld, is, you will rid the metal of oil or grease. Cast iron being porous will absorb the oil and grease and when the metal is welded the oil will form a gas which in escaping will leave pin holes in the weld greatly weakening it. So great care should be exercised in the removal of all oil and grease before the welding operation takes place.

The weld cannot be too clean, so be sure your parts are as free from oil, grease and any other impurities as you can make them before starting the welding operation.

Under this heading, the preparation of the weld, also would be classed the preheating of parts to be welded.[2] This is one of the most important points. Preheating is necessary where the castings are of such a shape that a suddenly applied heat on a certain point will cause a warpage or where there is not a free end for the expansion and contraction to take place.

In the welding of auto cylinders, small pump cylinders and other spherical shapes the parts, after being thoroughly cleaned and chamfered, should be brought to about 500 to 600 degrees Fahrenheit, which should be found sufficient. In the welding of large cylinders and spheres 900 to 1000 degrees Fahrenheit will be required. Should you build a furnace around the part to be welded be very sure that your flame used for preheating, especially if air pressure is used in conjunction with the preheating flame. does not play on your casting. If it plays directly on a part of the casting it will cause uneven heating causing warpage. Have your flame so placed as to slowly and evenly heat your casting and bring all parts of the casting to the same point of heat at the same time. Care should be taken to so regulate your preheating flame that the heat radiating from the welding operation will not cause the casting to become heated to too high a point as warpage will be the result.

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[1] *See "Beveling."*
[2] *See "Preheating."*

Preheating is something that must be left to the knowledge and experience of the operator as some operations require but slight preheating while others require the limit. But always remember that parts heated too highly will warp.

Second: The Selection of a Proper Filler Rod.

You cannot exercise too much caution in selecting a filler rod. Always get the best. A dirty inferior rod will mean, waste of gases, waste of time, and an inferior weld, no matter how skilled the operator. As your heat has a direct effect on the carbon and silicon contained in the filler rod, lowering or burning out a percentage of both the carbon and silicon, special attention should be paid to the amount of silicon and carbon contained in the rod. Therefore, the carbon and silicon content of the rod should be comparatively high. A clean, high silicon rod is the best.

Third: The Selection of a Proper Size Tip.

Be sure and select a tip large enough. We say large enough because there seems to be a tendency to select too small a tip and try to overload or crowd it. This is a bad practice as it causes flashbacks and also localizes the heat to such a small area that it radiates too quickly thereby chilling the line of weld, making a weld hard to machine. Also you will have difficulty in controlling your metal when it is in a fusing state as it will be blown on the cold parts of the line of weld, causing an inferior weld. By using a tip large enough and not crowding it you will have no difficulty with controlling your metal when in the fusing state.

Fourth: The Regulation of the Welding Flame.[3]

Be sure your flame is neutral. An excess of oxygen means oxide films and slag pockets. An excess of acetylene means pin holes. In both cases a weakened weld. If you carry an excess of acetylene the metal when in a molten state will take up, or absorb, the excess acetylene gas and when it escapes in the cooling, or solidifing of the metal would leave pin holes. Such is also the case when the weld is not cleaned of all oil and grease. So always use a neutral flame.

Fifth: The Welding Operations.

After the casting or part has been preheated to the proper temperature apply the flame to the bottom of the V. Be sure and fuse the bottom of the V first at the same time heating your sides and bringing them up to a point of fusion, then apply your filler rod, breaking up your oxide film and raising your impurities with the filler rod. Always be sure to raise all impurities to the top of the weld where you can float or lift them off. Do not push the impurities to the edge and let them lie there as they will leave hard spots impossible to machine. Lift them out and fuse the edge of your weld thoroughly. Do not play your flame any longer than necessary on one spot, as by doing so you are burning out properties impossible to replace. Keep an area on both sides of the line of weld at a high temperature so that the cooling process will not take place too rapidly. Do not use any more flux than positively needed. Your flux is simply to help break up the oxide film and dissolve the impurities.

Sixth: The Cooling Process.[4]

This has more to do with making welds machinable than most operators imagine. If the above suggestions are carefully followed then the only reason for hard welds, would be rapid cooling. Rapid, uneven cooling will make hard welds, will result in warpage and make castings crack again after being apparently successfully welded. Whenever possible, the line of weld and an area on both sides should be brought up to about 1,000 degrees F. before being put away to cool. If you make sure your work will cool slowly and evenly there should be no reason why your welds should not be machined easily. Also you will have no trouble with warpage, strains and cracked castings. The slower and evener your castings cool the nearer your weld will be like the original metal of the casting welded.

[3] *See "Flame Chart."*
[4] *See "Cast Iron—Hard Spots In."*

WELDING OF COPPER BRASSES AND BRONZES*

By M. Amedo

Metallurgical Engineer to the Union de la Soudure Autogene. Translated with additions, by D. Richardson, Wh., Exh., A. M. I. Mechanical Engineer. Member of the Union de la Soudure, Autogene.

Many welders, astonished at the ease with which they obtain sufficiently strong welds on mild steel, attempt to weld copper and its alloys by utilizing the same methods. For example, they use as a welding rod a strip of metal cut from the plate itself, or a wire of the same nature, with the result that the welds obtained by these simple methods are of little practical value. Skillful manipulation of the blow pipe alone is insufficient for producing strong welds, because copper melted by the flame of the torch is no longer pure. The added metal—in other words, the welding rod—should contain elements capable of preventing defective welds due to changes in the metal of the joint, and the autogenous welding of copper and its alloys is only possible when the welding rod is specially made for each metal or alloy is used.

From time to time heterogeneous alloys under special names have been proposed for the welding of copper, usually by individuals incapable of appreciating the distinction between the real autogenous weld and a mediocre brazed joint. Failures, following the use of these mixtures, have largely been responsible for the belief that it is impossible to obtain perfect welds on copper and its alloys.

In addition to the deplorable results obtained by using these "special" metals, it is of interest to examine the resistance offered by parts welded with metals manufactured specially for supporting, without alteration, the melting with a welding torch. The results of tests demonstrate that the best method of obtaining encouraging results in oxy-acetylene welding is to apply in a rational manner a method of work scientifically established.

Oxy-Acetylene Welding of Copper

Physical and Chemical Properties.—Copper stands alone among the metals in having a reddish color. The brick-red tint observed in the fracture of certain commercial coppers of bad quality, and also in many welds is due to the presence of appreciable quantities of oxide in the interior of the metal

The specific gravity of copper is about 8.9; its melting point is about 2,000 degrees F. (1,100 degrees C.). Copper is an excellent conductor both of heat and electricity. Owing to its high heat conducting power it is used for firebox plates and similar purposes, and this property, from a welding point of view, is a great disadvantage. The rapid conduction of heat from the part played on by the torch flame frequently leads to the defect of adhesion instead of welding, and thus every precaution must be taken to combat loss of heat, which sometimes completely prevents melting of the metal and always increases the time taken to do the weld.

The high conductivity for heat of copper slows down the cooling of the lines that have just been welded, and this increases the possibilities of fracture, because the tensile strength of copper in the heated condition is very low.

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The strength of copper at ordinary temperature—which is in the neighborhood of 16 tons per square inch—is diminished by more than 60 per cent when the temperature of the metal is raised to 930° F. It is therefore necessary to conduct the welding operation in such a manner as to avoid fractures due to contraction.

The welding of copper conductors, omnibus bars, etc., does not modify the resistance in the welded joint, but the electric conductivity is diminished very considerably by even slight traces of impurities.

The presence of impurities also modifies many of the mechanical properties of copper, The fractures produced when welded articles are machined or worked hot, and which are generally attributed to defective welding although often outside the weld altogether, are very frequently due to impurities in the metal itself.

Bismuth is the most objectionable impurity, as even a very small quantity renders the metal so brittle that it cannot be worked either hot or cold. Antimony and arsenic have very similar actions, but the former is much more objectionable. Arsenic hardens copper and increases its tensile strength, and for many purposes its presence is not only not objectionable, but is advantageous. Phosphorus ameliorates the mechanical properties, but when the quantity is large the metal is rendered very brittle.

Copper is comparatively soft and flows readily under pressure, so that it is both malleable and ductile and can be rolled into thin sheets or drawn into fine wire, and can be worked into any required form by stamping or spinning. When the metal is worked it becomes hard and to a certain extent loses its ductility, but it is restored to its proper degree of toughness by annealing. When copper is being worked it must be repeatedly annealed to avoid fracture. It should be possible to hammer an oxy-acetylene weld on copper until the metal is quite thin without showing any crack.

The ultimate strength of copper is approximately:

	Pounds per square inch
Copper castings	19,000 to 26,000
Ordinary	33,000 to 26,000
Pure wrought	36,000 to 26,000
Copper wire	38,000 to 60,000

The specific heat of copper is about 0.094 and its co-efficient of linear expansion 0.000006 for each degree Fahrenheit rise of temperature. Copper is not acted on by dry air or oxygen at ordinary temperatures. It comes into the market in ingots of various sizes. The principal varieties of commercial copper are:

1. Electrotype copper, prepared by electro deposition from solution. It is usually very pure.

2. Best selected (B. S.) copper. This is a very pure form, and is mainly used for the manufacture of alloys.

3. Tough copper. This is the ordinary commercial copper.

The Melting of Copper

The melting of copper in contact with the atmosphere is always accompanied by chemical and physical phenomena which always tend to diminish the qualities of the metal.

A copper weld executed with a very pure copper welding rod—electrotype, for example, will be found to be riddled with blow holes. These blow holes are easily shown by cutting the weld transversely and then, after polishing the surface, usually by fine grinding on emery papers of increasing degrees of fineness, treating the polished surface with a solution of ferric chloride acidified with hydrochloric acid or other suitable etching fluid.

The density of copper melted with the blow pipe, is diminished very largely by the presence of blow holes. The blow holes are caused by the absorption of gases and, in the case of pure copper melted with the oxy-acetylene torch flame, on solidification a phenomenom similar to the "spitting" of silver takes place.

If the oxy-acetylene flame contains an excess of acetylene the absorption of gases and the apparent boiling of the metal are considerably increased.

Copper in the molten condition oxidizes very rapidly; this oxidation is extraordinarily intense, and is capable of transforming the metal into an actual alloy of copper and copper oxide.

Oxidation of Copper, Constitution of Copper Oxide

Whenever copper is melted in the presence of air it forms an oxide which is very rapidly dissolved in the metal. It is practically impossible to have perfectly pure copper in the molten state, as it is difficult to avoid contact with the atmosphere. It is for this reason difficult to find exactly the melting point of copper. The temperature taken in a molten bath of copper is that of a mixture of pure copper and dissolved oxide.

The melting point of copper, containing copper oxide up to the point of saturation, is 1.068 degrees C. (1,956 degrees F.). This temperature is the melting point of the eutectic alloy of oxide and copper containing four to five per cent of oxide.

This oxide, or cuprous oxide (Cu_2O) as it is called, can, after solidification, be present in the weld in several states. It may be isolated in bluish crystals grouped in tree-like forms and known technically as a "dendritic" structure. At other times the metal consists of islets of pure metal surrounded by the alloy of copper and copper oxide previously mentioned.

The presence of crystals of oxide or of the eutectic of oxide and copper in the interior of a weld renders the metal brittle, and cracks are produced under shocks from a hammer. Appreciable amounts of oxide present are shown by the appearance of the fracture which in such cases is granular and of a dull red color. Cuprous oxide present in small quantities is not harmless—in fact, in ordinary commercial copper the presence of a certain proportion of copper oxide is found essential to the good quality of the metal.

The oxidation of copper is therefore always produced when the metal is melted. The oxidation is diminished by limiting its contact with the atmosphere.

The Influence of Flame Regulation

The nature of the flame of the blow pipe influences the fusion of copper. It is well known that the properly regulated flame gives as the products of the first phase of the combustion hydrogen and carbon monoxide, but this does not prevent the inevitable oxidation by the atmosphere.

An excess of acetylene in the flame increases the effervescence or bubbling of the metal. A weld made with such a flame contains therefore a very large number of blow holes. Again, the formation of oxide being due to the oxidizing action of the atmosphere, the effervescence of the copper produced by the excess of acetylene exposes more surface of metal to contact with the air and the oxidation is considerably increased.

An excess of oxygen gives, in the part of the flame utilized for welding, carbon dioxide and water vapor. Carbon dioxide gas possesses the curious property of diminishing the absorption of gases. The melting of the metal in the presence of an oxidizing flame is therefore very calm and no effervescence is produced. Nevertheless, carbon dioxide and water vapor are energetic oxidizing agents at high temperatures, and it follows that the oxidation of the metal is very intense. **It is obvious, therefore, that the welding of copper should be done with a flame normally regulated.**

The torch head should be held in such a manner that the white part of the flame, commonly known as the white cone, is at a distance of ¼ to ⅜ inch from the surface of the metal. If the separation is too considerable, in other words, if the tip of the white cone is at too great a distance from the metal, the intensity of the oxidation of the metal is increased, due to the fact that as the distance is increased, the outer mantle of the flame, containing carbon dioxide and water vapor, come into contact with the molten metal.

Conditions that should be fulfiilled by a welding metal or rod for use in the welding of copper.—In welding copper the welding rod used should satisfy the following conditions:—

(1) In order to render the work easy, its melting point should not be different from that of copper.

(2) In order to give a weld free from blow holes it must absorb as little gas as possible.

(3) It should contain a deoxidizing element capable of destroying the dissolved oxide. This deoxidizing element should diffuse very readily in the molten metal and give, by the reduction of the oxide, a slag which has no tendency to remain imprisoned in the metal. It is further necessary that the percentage of the deoxidizing element should be just sufficient to purify the metal melted under the blow pipe, as **an excess of the deoxidizer may modify the mechanical properties of the weld.**

The use of electrolytic copper does not satisfy these conditions; moreover the welds made with pure copper lack strength because it is impossible to destroy the oxide formed during the welding operation.

It is not possible to destroy the oxide of copper with a flux, no matter what composition of flux is used. The newly formed oxide is dissolved in the molten mass and is unaffected by the superficial action of a flux.

Phosphorus is probably the best known and the most generally used of all the deoxidizers. It was first used in copper and brass by Parkes of Birmingham in 1849. The addition of phosphorus to copper and its alloys is well known to improve the mechanical properties of the metal, particularly if the quantity is carefully adjusted. If the phosphorus is added in the form of a phosphorus-copper alloy **it readily diffuses throughout the molten bath,** destroying the dissolved oxide. During this purification of metal the phosphorus is converted in phosphoric oxide which is capable of dissolving a further quantity of oxide. The slag thus formed is very fluid and rises to the surface of the metal, where it **forms a protecting film isolating the molten copper from the atmosphere and the gases of the blowpipe.**

In addition to being a powerful reducing agent, phosphorus considerably reduces the absorption of gases. It follows, therefore, that a weld made with a welding-rod containing phosphorus will tend to be free from oxide. Again, if phosphorus is present during the melting of copper there will be little tendency to oxidize, because this element suppresses the bubbling of effervesence or the molten metal, which is one cause of oxidation, and the phosphoric acid formed on the surface of the metal keeps the molten metal from contact with the atmosphere—the initial cause of oxidation.

It is for these reasons that a welding rod containing a quantity of phosphorus based on a calculation made from the amount of oxide found in a weld normally executed is much too rich in phosphorus.

From a welding point of view phosphorus gives the best result as a deoxidizer. Aluminum, for example gives good results, but possesses the troublesome property in welding of making the molten metal much too fluid. In addition, it is very difficult to manufacture a perfectly homogeneous welding rod containing aluminum.

For electrical purposes the presence of oxide is particularly undesirable, but the use of phosphorus for its removal is not entirely satisfactory, owing to the fact that any slight excess of the metalloid remaining in the copper would seriously affect its conductivity and mechanical properties. For that reason a more satisfactory deoxidizer for copper has been sought, and it it believed to have been found in the substance known as boron suboxide.

The Phosphorus-Copper Alloy Welding Rod

The welding metal used for the oxy-acetylene welding of copper is therefore a phosphorus copper alloy.

A very small quantity of phosphorus is incorporated in the metal, just **sufficient to obtain metal free from oxides.**

The phosphorus is present in copper in the form of a white solution, and its resistance to corrosive agents is much greater than that of the copper itself. The precentage of phosphorus in this phosphorus-copper alloy does not reach one per cent.

At the moment the metal melts under the torch the phosphorus contained in the welding rod automatically deoxidizes the molten metal, and the phosphoric oxide formed rises and floats on the surface of the metal. It is obvious, therefore, that to remelt a copper weld with the torch flame oxidizes the metal.

Welds on copper should never be remelted without a new addition of welding rod, and, further, in order to improve the appearance of the welds, no superficial melting with the torch should take place unless fresh welding metal is added.

The presence of undissolved particles of phosphorus always produces fracture of the wire during the wire-drawing operations, and causes the welding metal to lose its malleability.

The presence of free phosphorus is easily recognized under microscopic examination by the presence of white islets surrounded by dark parts of undissolved phosphorus. An electrolytic attack with a solution of hyposulphite of soda darkens for a time the copper and the phosphorus in solution, after which the grains of undissolved phosphorus appear blue.

The Welding Rod too Rich in Phosphorus

A metal too rich in phosphorus lacks fluidity and, in addition, melts at a temperature slightly lower than that of pure copper, thus making it easier to obtain the defect of adhesion.

It is very difficult to get an intimate joining of the added metal with the chamfered edges. It is generally found that a sudden variation in the percentage of phosphorus takes place in passing from the metal melted by the torch flame to the metal of the plates.

A weld of this type submitted to the bending test always separates along the chamfered faces.

When the percentage of phosphorus after welding exceeds 0.2 this would correspond to using a welding-rod much too rich in phosphorus, and such a weld would possess little elongation properties.

The electrical resistance of the metal increases very rapidly with the increase of the percentage of phosphorus. The conductivity of pure copper being taken as 100, that of pure copper containing 0.13 per cent of phosphorus is not more than 70.

In welding electrical connections the use of a welding-rod containing too much phosphorus leads to the resistance of the joint being higher than that of the copper, and as a result, heating the joint takes place, especially in the case of high amperage.

The use of a welding-rod of too large a diameter for welding thin material produces welds containing an excess of phosphorus because the welding-rod is melted in larger masses and is accompanied by less oxidization, which in turn is incapable of utilizing the major portion of the phosphorus which the rod contains.

Execution of Copper Welds

It is important in the first place, to note that it is useless to attempt to weld two pieces of copper unless the edges to be welded and their surrounding parts have been raised to a very high temperature near the melting point.

In fact, if the borders of the parts to be welded are not very hot for a certain width, the constant conduction of the heat by the rest of the piece cools the lines of welding whilst the welder is obtaining the molten bath and melting the rod in the chamfer. The result is that the faces of the chamfer solidify whilst the added metal remains molten, and the welder gets the impression that he is executing the work in a normal manner, whereas he is getting the defect of **adhesion.**

It is therefore indispensable to maintain the environs of the parts to be joined, at a very high temperature during the execution of the work.

Those welders who assert that, in order to obtain good copper welds, it is necessary immediately before welding to heat the surrounding parts of the weld much more than the joint itself, are in the right. The numerous adhesions in copper welds are due to neglect of this precaution.

Preheating of Copper

It may be stated, as a principle, that the welding of copper should always be preceded by heating. If the welder is content to bring the torch flame on to the lines of welding without previously heating them, the heat of the torch is wasted for some time, and when fusion is produced it is not sufficiently free and thus adhesion is obtained. The welding of thin plates of copper, at which so many welders fail, demonstrates clearly the necessity for constant heating of the parts to be joined.

To a welder, inexperienced on copper work, it may perhaps appear at first sight, that the use of a powerful torch tip on copper welds would lead to rapid work, as the melting of the edges is produced by a large quantity of heat from the torch. The majority of plates welded on this supposition are simply glued to the added metal.

To successfully weld thin plates of copper, care must be taken not to weld with the white cone too near, as this may be too powerful for melting a very thin layer of metal. On the other hand, the weld should be done with the welding flame held sufficiently far away to give a flame which heats both edges of the weld, and the joint itself.

The preheating of bars or small pieces of copper may be done with a simple charcoal fire, and therefore the preheating of small articles is always a simple matter.

The problem becomes much more difficult when it is a question of preheating large bodies, such as thick tubes or plates of appreciable size. The most simple method, where the length to be welded is short, is to heat the opposite face with another torch, which should be at least as powerful as the torch used for the actual welding operation.

This method of heating is not practicable when the seam is very long, because in this case the heating by the blowpipe is too irregular. The weld progresses too rapidly in some places and too slowly in others, and the plates have considerable movement, necessitating frequent stoppages for adjustment. The best method in this case is to make a temporary fire below the weld with a suitable ventilator. In this way a uniform temperature is obtained in the immediate neighborhood of the weld, and the work can be carried out rapidly and regularly. To prevent loss of heat by radiation it is well, where possible, to make good use of sheet asbestos, the work is then carried out by the welder with much greater facility.

Whatever method of heating is used—and preheating is indispensable for producing good work—it should not be carried too far because the welder may not be able to control the melting of the metal, and sometimes large holes and the sinking of the metal interrupt the work.

To sum up, the indispenable condition for obtaining good welds on copper is to obtain a good **uniform heating of the edges to be welded and their immediate neighborhood.** In this manner the defect of adhesion is avoided, otherwise it is very common.

The Use of Asbestos

When welding thin sheets of copper and even plates of medium thickness, it is advisable to place under the lines of welding, and, in the case of thicker material, at the sides, an insulating material, such as, for example, asbestos. If this precaution is not taken, a considerable thinning of the material takes place in the region of the weld, due to the sinking of the metal.

The asbestos may be used in the form of sheets or millboard. The disposition of the asbestos in the case of plates is shown in Fig. 1, and in the case of tubes or pipes in Fig. 2. In the former, A is the plate bevelled

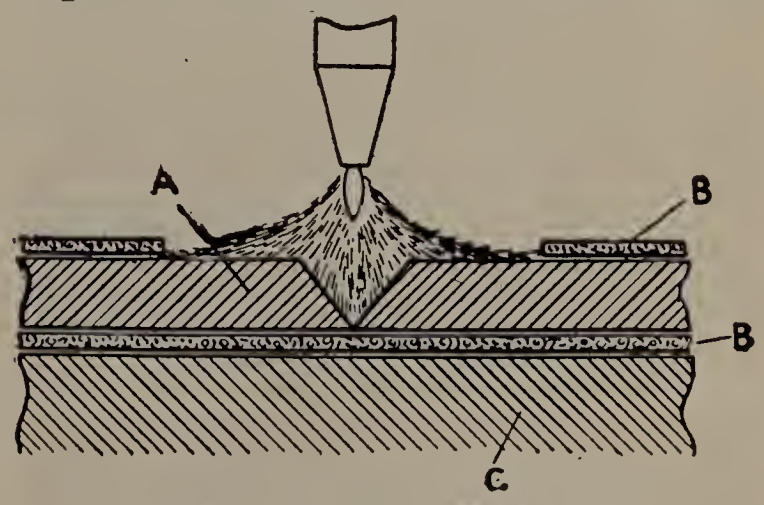


Fig. 1.—The Use of Asbestos.

and placed on a sheet of Asbestos B, which in turn is placed on a slab of firebrick or other similar material C. Asbestos is also placed on either side of the lines of welding as shown at B. In welding tubes or pipes. a layer of asbestos is arranged on a mandrel or tube and placed under the line of welding as shown in Fig. 2, where A is the tube and C the mandrel covered with asbestos B. This simple arrangement can also be used in the welding of plates.

It is advisable, before commencing to weld, to play the torch flame over the asbestos which will be in the vicinity of the under side of the weld. The precaution avoids the

formation of numerous blowholes on the under side of the weld, as commercial asbestos always contains organic materials and moisture.

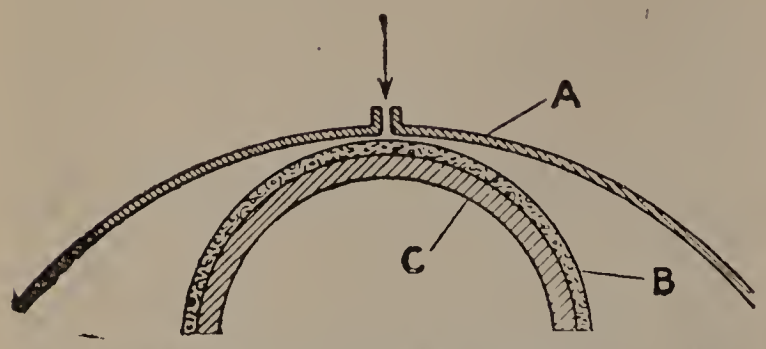


Fig. 2.—Mandrel Coated with Asbestos. Used in Copper Pipe Welding.

The Position of the Torch

The torch should be held almost perpendicular to the surface of the work so as to avoid driving the molten metal along the bottom of the chamfer.

The white cone of the flame should never be dipped into or come in contact with the molten metal. It should be kept at about a distance of a quarter of an inch from the molten metal. If the heating is done under

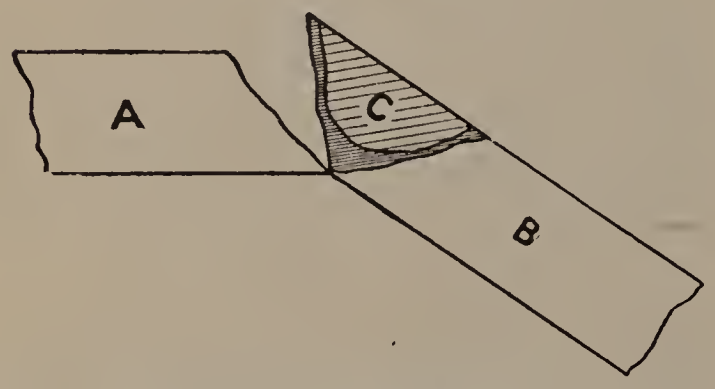


Fig. 3.—"Burning" and Separation Along the Chamfered Edges.

proper conditions, the melting of the edges of the weld and their mixture with the welding rod should be produced freely without any fear of overheating the lines of welding.

Some welders execute copper welds by welding "backwards" or towards them; this method of working is bad as it prolongs the overheating of the metal and consequently facilitates the cracks due to contraction.

Diameter of Welding Rod

The section of the welding wire for work on thin material should always be much greater than in the case of welds on iron and steel. Even in the case of very thin material, the wire should have a minimum diameter equal to 14 gauge. If the wire is too thin it burns under the action of the torch flame. As mentioned previously, the use of a welding wire of too large a diameter has the same disadvantages as using a welding wire containing too much phosphorus.

Flux

Theoretically it is not necessary to add a flux for the welding of copper. However, if the edges become dirty from any cause whatever during the welding operation, it is advisable to use a flux. It is also necessary to use a flux on repairs or old material. The **flux is the same as that used in** welding brasses and bronzes which will be dealt with later.

Burning the Bevelled Faces of Welds

Very frequently the welds are simply glued along the bevelled faces, even when the heating has been carried out in a normal manner. This very serious defect in copper welds indicates defective work.

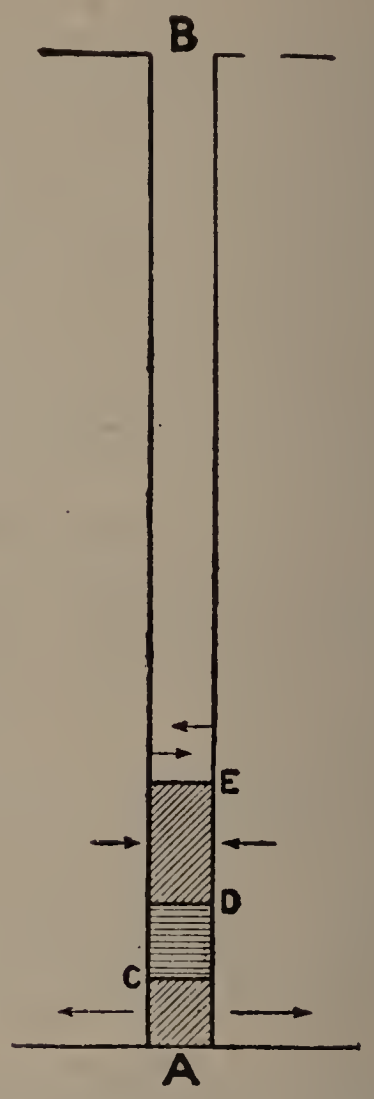


Fig. 4.—Contraction Effects.

It is important that the welder should remember never to melt copper unless the welding rod is present at the same time. The penalty for lack of this precaution is a heavily oxidized weld, or a "burnt" weld in the true sense of the word.

If a welder commences to weld copper by allowing the metal from the faces of the bevelled edges to fall in and partially fill the joint, he obtains as a result, a layer of burnt copper, of no value from the mechan-

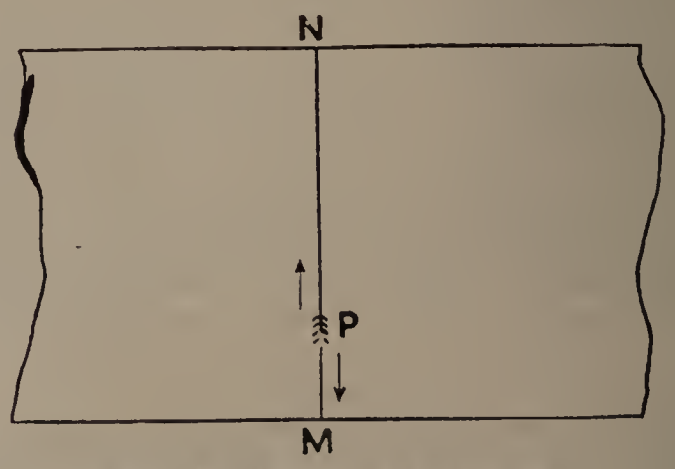


Fig. 5.—Method of Welding.

ical point of view. The metal added afterwards in the central part C (Fig. 3) is quite sound, but the weld as a whole is of no value, and if the joint is bent, separation takes place along the burnt edge as shown in Fig. 3. An examination along the

separated edges reveals very large blowholes which should not be present in a weld executed with the phosphorous-copper.

Such methods of work nullify the use of a metal containing a deoxidizer. The melting of the bottom of the weld or the bevelled faces should be progressive and always accompanied by the melting of the welding-rod, which, having once been placed in the joint, should remain until the same is complete.

It is just as defective to go over a part just previously welded without a new addition of metal capable of preventing oxidation.

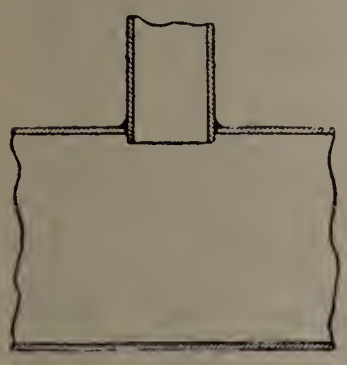


Fig. 6.

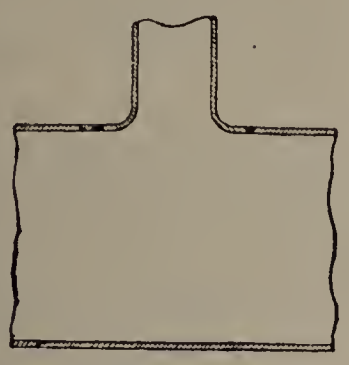


Fig. 7.

Contraction Effects.

It is necessary to take precautions to avoid cracks or fractures due to contraction. The cracks or fractures which take place in welds of great length are generally due to two causes:—

(1) The low strength of the cast copper which constitutes the joint.
(2) The reduction of this strength, even in portions some distance from the parts attacked by the blowpipe, by the high temperature effect of the blowpipe.

The methods of avoiding such fractures are:—

(1) To avoid or diminish the result of contraction.
(2) To increase the strength of the welded parts.

It seems difficult to realize the first of these conditions. It is, however, often possible to diminish the forces tending to fracture the metal during the course of welding.

Suppose, for example, it is a question of welding the seam of a copper pipe or even a straight weld (Fig. 4). The pure and simple execution of a weld on plates placed edge to edge inevitably leads to failure. A necessary preparation of the weld consists in separating the edges at B by an amount equal to 5 or 6 per cent of the length AB. Again, suppose the melting of the metal has reached E say, the portion DE rapidly soldifies with intense contraction effects. The portion CD behind DE being much cooler, the contraction is considerably less. The effect of the drawing together of the plates at DE is a tendency to lever open the plates at AC, the one CD acting as a fulcrum or pivot.

The bursting open of the plates at A is almost inevitable and a crack once started extends as the weld proceeds. If the point A is made very strong, the crack will take place in the welded lines during solidification and in the zone DE. The most simple method of avoiding cracks or fractures due to this cause is **never to commence welding at the extremities of the plates.** Suppose, for example, the seam MN (Fig. 5) is to be welded. The weld is commenced at some point P and welded towards N, the movement of the free ends at M about P as a pivot can be very clearly seen. Having completed the portion PN, it is a simple matter to weld the remaining portion PM, which is welded, needless to say, in the direction P to M.

The welding of patches or pieces on to tubes or pipes is frequently met with in copper welding, and the piece should be uniformly stamped to a radius of curvature distinctly smaller than the tube or pipe, in other words, the convexity is more pronounced. The construction stretches the piece, and a fracture is prevented, which, without this preparation, is inevitable.

In welding branches on to tubes or pipes, the preparation shown in Figs. 6, 7 and 8 are adopted.

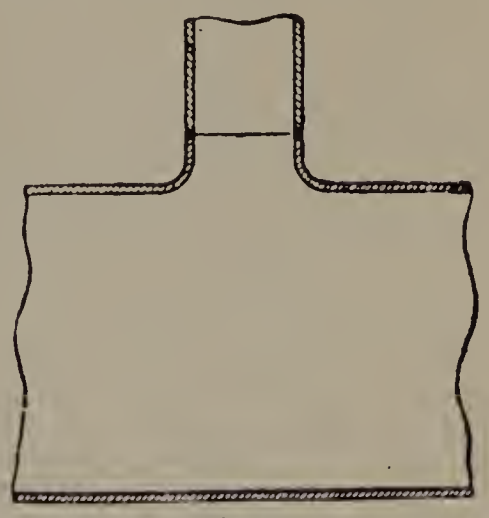


Fig. 8.

Fractures are almost sure to take place if the methods shown in Figs. 6 and 7 are adopted, because the contraction effects are different in the two tubes and the line of welding is too extended. The preparation shown in Fig. 8 where a flanged collar is formed on the larger tube, is the most satisfactory. In order to avoid cracks or fractures when the plates are worked in any way, it is necessary, as previously mentioned, to increase the tenacity of the copper in welded parts. The treatment which copper welds should undergo in order to increase their mechanical properties are always the same, no matter whether it is a question of simple end to end welds on bars or the welding of plates.

Hammering and Annealing Copper Welds

Assuming that the welds are sound, in other words free from oxide and blowholes, the metal in the joint and its immediate neighborhood is always in the cast condition, especially in the case of welds on thick material. The metal consists of very large crystals which are developed as a result of the high temperature reached by the metal in the vicinity of the molten zone.

The tensile strength of cast copper is about 20,000 pounds per square inch and its elongation is very small. By forging the copper, that is to say, by vigorously hammering the lines of welding and their immediate neighborhood, a metal with a much higher tensile strength is obtained. The tensile strength is raised to over 33,000 pounds per square inch, and the elongation is from 25 to 30 per cent. If these figures are compared with the figures for rolled copper plates, cold hammered and annealed, which have a tensile strength of 27,000 to 37,000 pounds per square inch and an elongation of 22 to 40 per cent (the maximum elongation corresponding to the maximum strength), it will be recognized that hammering is an excellent operation to apply to welds, giving them a strength sufficient for all practical purposes.

The hammering may be done hot for bars or very thick copper, but copper should not be hammered at too high a temperature.

After the hammering is completed it is advisable to anneal the copper by raising it to a red heat, and, where possible, plunging it into cold water or cooling off as rapidly as possible. The rapid cooling of copper, reheated to a temperature of 500 to 600° C (932° to 1,112°F.) greatly improves the

metal that has been overheated. The surrounding parts of a weld which has been hammered, annealed, and rapidly cooled, no longer consists of large crystals; the fragility of the whole joint is diminished and becomes tougher.

When working on a weld of great length it is advisable to execute the weld in sections which are afterwards uniformly heated and submitted to hammering whilst hot, followed by a new re-heating and then cooled off with water. Welds carried out in this manner can be worked or stamped without difficulty.

Copper plates are sometimes defective or contain impurities which entirely prevents the execution of a strong weld. Certain very pure copper plates made by the electrolytic process should not be welded. This variety of plate, which the welder should absolutely avoid, are easily recognized by a simple examination of the surface, the metal shows, in this case, a series of channels which give the copper a dull aspect.

Oxy-acetylene welding may be used with advantage for obtaining strong joints between the various cables or omnibus bars in electrical power stations. **The operation of welding does not modify the resistance of the conductors if the joints are welded in a proper manner with the phosphoretted welding rod.**

With regard to repairs the oxy-acetylene process is often the only process that can be applied for the restoration of pieces broken, worn, defective, cracked, etc.

OXY-ACETYLENE WELDING OF BRASSES

Physical and Chemical Properties

All alloys of which copper and zinc are the essential and chief constituents are called brasses. Alloys of zinc and copper are known in commerce by a variety of names. The alloys used for engineering purposes contain more than 55 per cent of copper, and within this range there is a very great variation of properties. Commercial brass never consists entirely of copper and zinc, since whatever impurities exist in the separate metals will also be found in the alloy —the most common of these being lead, tin, iron, and arsenic. It often happens that some of these are purposely added, to produce a given effect in the alloys. Certain varieties of brass are exceedingly malleable and ductile. The malleability varies with the composition, with the temperature, and with the presence of foreign metals. Some varieties are only malleable when hot, others can be rolled at any temperature. Alloys containing up to 35 per cent zinc can be drawn into wire, but those containing 15 to 30 per cent of zinc are the most ductile.

Brass is harder than copper, and therefore better adapted to resist wear and tear. It acts well under the process of stamping, provided it is suitably annealed at proper intervals. Crystallization is induced by work; hence the necessity for frequent annealing when the metal is worked cold. In annealing brass the temperature employed for annealing is of the greatest importance, for if the temperature is too low, the annealing is of no value; and if too high, the metal is spoilt, the effect produced being technically known as "burning." These effects will be dealt with later.

From a welding point of view brasses can be grouped into two distinct classes—namely, brasses containing 65 to 70 per cent of copper, which can only be worked cold; and brasses containing 55 to 65 per cent of copper, which can be worked hot. It is absolutely necessary to weld each variety of brass with a welding wire of the same character, and it is fairly easy, knowing the use to which the material is to be put, to find approximately its composition. A large number of varieties of brass are in use, and the following summary will serve as a guide to the composition:

Sheet Brass and Wire Brass

For alloys of a full yellow color, the most suitable proportions are found between 66 to 73 per cent of copper and 34 to 27 per cent of zinc. For hot rolling, the alloys known as Muntz's metal, or, more commonly, yellow metal, are employed. They vary in composition from 56 to 63 per cent of copper and 42 to 37 per cent of zinc. The composition of brass for ordinary wire drawing varies from 67 to 72 per cent copper, and 33 to 28 per cent zinc. A little lead is sometimes added to brass intended for rolling to facilitate machining and filing the metal.

Cast Brass

The composition of brass used for castings varies considerably. The composition most generally used consists of 66.6 per cent copper and 33.4 per cent zinc, which is termed English standard brass. From 1 to 2 per cent of lead is usually added to brass castings required for turning and filing. Cast brass is often more impure than rolled brass, a large quantity of scrap being generally melted with the new metal.

Delta-metal, Sterro-metal, and Aichs-metal are modern brass alloys containing a small quantity of iron, their composition brings them into the second class already mentioned.

Many brasses used in machinery contain a little tin, which hardens and strengthens the alloy.

The melting-point of brass is lower than that of copper, and falls steadily with decrease of the percentage of copper. A brass in the first class melts in the neighborhood of 1700 deg. F. (930 deg. C.), whilst a brass in the second class melts at about 1620 deg. F. (880 deg. C.). The heat conductivity of brass is less than that of copper, and molten brass is very fluid.

The color of the alloys vary very much. A very small quantity of zinc destroys the red color of the copper. The color becomes brass-yellow, being strongest when the metals are present in about equal quantities then it becomes rapidly paler, and when the copper falls to 40 per cent it is almost silver-white, after which it becomes greyer, and approaches more nearly the color of zinc.

The tensile strength of brass gradually increases as the zinc increases from 0 to 35 per cent, then more rapidly up to about 45 per cent zinc, when it is at a maximum, then it rapidly decreases with more zinc. In a similar manner the elongation increases with the percentage of zinc, and reaches a maximum at about 30 per cent.

The Melting of Brass

The melting of brass by the torch flame is accompanied by three distinct phenomena:

1. The absorption of gases.
2. The volatilization of the zinc.
4. Oxidation.

The Absorption of Gases

This is less intense than in the case of copper, and the composition of the flame has very little influence in the melting of brass. The diminution in the boiling effect —which has been mentioned by several writers—when a flame containing an excess of acetylene is used is simply due to the fact that the temperature in this case is lower than when using the normal flame. To obtain a tranquil melting with the normal flame it is only necessary to keep the white cone of the flame a short distance from the molten metal.

The use of an oxidizing flame gives, of course, an increased oxidation effect.

The Volatilization of the Zinc

The most striking phenomenon in the melting of brass by the torch is the volatilization of the zinc. The vapors of zinc burn and are converted into the white fumes of the oxide on coming into contact with air. The white fumes are unpleasant to breathe, and are deposited on the surface of the work, on the torch, and on the welder himself.

This volatilization of the zinc is not surprising, as the metal in fact, gives off abundant vapors some time before reaching its boiling point as 1725 deg. F. (940 deg. C.). The melting point of a brass, say in the first class, being about 1700 deg. F. (930 deg. C.), and as this temperature is very near to the boiling temperature of the zinc, the zinc vapors are produced in large quantities.

In the case of a brass in the second class, which melts at a lower temperature, the volatilization of the zinc tends to be less intense, but as the percentage of zinc is higher, experience shows that the production of the white oxide fumes is practically the same with the two classes of alloys.

With regard to the brass containing 10 per cent of zinc, known as Tombac, which is sometimes used in error as a welding metal for welding copper, as the boiling point of the zinc is clearly passed, there is produced, in spite of the small percentage of tin in the alloy, a large quantity of oxide fumes, and the metal is generally burnt during the welding operation.

This loss of zinc by volatilization varies considerably according to the thickness being welded and the experience of the workman handling the torch. It may reach a fourth or fifth of the total quantity of zinc contained in the metal, and varies from one part of the joint to another.

It might be supposed that this loss of zinc could be compensated for by making use of, as welding rods, alloys containing a low percentage of copper. For the reasons stated above this method does not produce the desired result. The most satisfactory method of avoiding modification of the metal due to the volatilization of the zinc is obviously to suppress it. This result is obtained by the addition of a very small quantity of aluminum to the metal to be used as a welding material. Aluminum, in fact, completely suppresses loss of zinc by volatilization*; it also renders equally valuable service from the point of view of the deoxidation of the metal and prevents pinholes, which are the despair of welders working on brass, by suppressing the absorption of gases.

The Oxidation of Brass. The Deoxidation of the Metal

The loss of zinc from brass melted by the torch is not altogether due to its volatilization. Both the copper and the zinc in the alloy are oxidized under the influence of the air, but the copper oxide is reduced by the zinc, so that the loss of zinc by oxidation of the alloy is, in a sense, doubled—that is to say, oxidation of the zinc itself and oxidation of zinc at the expense of the oxygen in the copper oxide.

This oxidation robs the alloy of zinc and covers the molten brass with a light coating of oxide which leads to adhesion at the chamfered faces. Aluminum being a very energetic deoxidizer, prevents the oxidation of the zinc,* the alumina formed protects the metal from oxidation and the dissolution of gases.

If the oxidation of the metal is not very intense, the elimination of the aluminum may not be complete, but the presence of slight traces of aluminum in a weld is no serious disadvantage.

**In the manufacture of brass the presence of small traces of aluminum serves to diminish the loss of zinc.*

Welds obtained with welding wires corresponding to the first or second class brasses are very sound. The joining of the added metal with the edges of the weld is perfect.

Heat Treatment of Brass Welds

Annealing is always valuable for the alloys containing between 65 and 70 per cent of copper. The operation of annealing is useless for the brasses containing more than 70 per cent, or less than 65 per cent of copper.

Practically, it can be said that annealing is indispensable for brasses in the first class—in other words, for the brasses that can be worked cold. Brasses in the second class should only be annealed to remove the effects of cold-hammering, a treatment always advisable for welds which have to withstand great strains.

The annealing of brasses makes the structure of the whole article uniform. The best combination of strength and ductility are obtained for annealing temperatures between 600° and 700° Cent. (between 1112° and 1292° Fah.).

Brass should not be annealed at too high a temperature. Annealed at 800° Cent. (1272° Fah.) the crystals become very large. If the temperature of annealing is too high and the annealing maintained for too long a time, "burnt" brass is obtained, which is characterized by its feeble strength and an elongation practically nil.

The Welding Metal for Brass

The welding wire intended for the welding of brasses should be manufactured from new metals. The zinc should be of good quality, so as to avoid incorporating into the metal impurities, lead, etc., capable of facilitating the burning of the metal.

The quantity of aluminum added should be very small, because aluminum—as is shown by M. Guillet in his researches on brasses—very rapidly raises the zinc equivalent; 1 per cent of aluminum is equivalent to the addition of 3.5 per cent of zinc; this is valuable in controlling the manufacture of welding wire.

The color of the alloy is changed by a quantity of aluminum which would be considered small, especially in the case of second class brass, which has a tendency to become a beautiful golden color. A weld executed with a rod of this type is therefore very obvious, and this may be a serious disadvantage in certain applications.

Execution of Brass Welds. Preparation of Parts

The edges are beveled with a single or double bevel according to the thickness of the metal. A welder who operates on material above ⅛ inch thick without having previously beveled the parts invariably obtains adhesion, lack of penetration, excessive consumption of gases, burnt metal—in short, very defective welds. Careful experiments have shown that the cost of gases in the case of unprepared welds exceeds by 25 per cent the cost necessary to execute the same work properly beveled.

The angle of the bevel considerably affects the mechanical properties of the weld. If the angle is too small, or not carried to the bottom edge, it is difficult to get good penetration and to avoid adhesion in the lower part of the weld. The bevel which gives the best results from all points of view is that in which the beveled plates form an angle of 90°—in other words, the entire thickness of each side should be beveled to an angle of about 45°.

The immediate neighborhood of the weld should be carefully scraped clean. The defect of adhesion, more or less common in brass welds, is frequently due to neglect to properly clean the parts. There is no time for the flux to destroy the oxide and greasy matter which usually coat the metal, and

the flame of the torch does not destroy them. In welding large articles it is advisable to preheat the environs of the weld, taking care not to raise the temperature above 930°F. (500°C.).

The size of torch tip to use should be greater than that which would be necessary for welding the same thickness of mild steel, and should be slightly higher than for welding the same thickness of copper, in order to obtain free fusion of the edges of the weld.

The actual welding operation should be preceded by heating the edges of the weld, and this can be done by the lateral displacement of the torch flame. If this precaution is neglected, the melting of portions of the edges of the weld would be insufficient, and adhesion along the beveled edges would follow.

The molten metal is very fluid, and this tends to the formation of holes. The use of the proper welding wire containing aluminum has a marked effect in diminishing the fluidity.

The welder should avoid surrounding the parts to be welded with fireclay or similar material to prevent the molten metal running away. The usual method of supporting the work on firebricks should also be avoided, because the gases contained in these refractory materials are set free, under the influence of heat, during the welding operation, and, owing to the fluidity of the metal, very large blowholes are formed throughout the welded zone.

Melting the Edges of the Weld

As in the case of copper, the melting of the metal of the piece should take place without the necessity of bringing the white cone of the flame in contact with the beveled faces. If the work is of large dimensions, the heating of the edges of the weld should be sufficiently intense so as to reduce to a minimum the cooling of the beveled faces, due to conductivity, and prevent adhesion by premature solidification.

In order to avoid oxidation, it is important that no melting of the metal of the work to be welded should take place without incorporating a certain quantity of welding metal.

During the welding operation it is necessary to add regularly in the joint a certain quantity of flux, and for this purpose it is only necessary, from time to time, to dip the welding rod into the tin containing the powder.

Flux

Borax does not give satisfactory results from the point of view of cleaning the metal, and does not possess the requisites of a good flux. A good flux for brass melts at a high temperature and insures the perfect cleaning of the metal. The powder when melted covers the molten brass, thus protecting it from oxidation, and the good joining of successive additions of metal is facilitated. The proper flux, which may be purchased from a reliable company—preferably from one making a specialty of this particular line—dissolves the oxide of aluminum which sometimes favors adhesion. **To obtain sound welds, etc., the use of a flux is indispensable.**

Hammering and Annealing Brass Welds

Hammering considerably improves the mechanical properties of brasses. It should be done cold for brasses containing 65 to 70 per cent of copper, and brasses containing 55 to 65 per cent of copper should be forged hot, **taking care not to continue the hammering after the temperature of the metal falls below 930 degrees F. (500 degrees C.), because at this temperature brass becomes very brittle.**

After hammering, brass should be annealed within the limits of temperature previously indicated.

Brass should never be dipped into cold water while hot, as this makes the metal brittle.

Mechanical Strength

The strength of well-executed brass welds is in itself sufficient to specify the use of oxy-acetylene welding for the manufacture of various articles.

A weld on brass containing 65 to 70 per cent of copper, properly hammered and annealed, can be energetically forged or intricately stamped without showing any signs of cracks. For example, the writers have beaten out a weld, executed on sheet brass ⅛ inch thick, to a thickness of 1/100 inch thick without showing any signs of a crack either in the weld itself or in the surrounding parts. Brass welds on material up to 1¼ inch thickness can always be compressed without showing cracks.

The Welding Metal for Bronze

The welding rod to be used when welding bronzes should always contain a definite percentage of phosphorus and **very small traces of aluminum.** The welding rod should only be used in the cast form and its manufacture should be very carefully supervised, especially in the case of the alloys containing the higher percentages of tin. The temperature at which the welding rod is cast is also of very great importance in obtaining a uniform and homogeneous metal.

An excess of phosphorus in the welding rod is not a disadvantage in the case of bronze; on the contrary it is an advantage to leave traces of phosphorus in the welded parts so that welding rods richer in phosphorus than other filling alloys are obtainable for work of the type of repair to gear wheels, etc.

The Superficial Loss of Tin Preceding Welding

If the white cone of the flame is applied directly on the edges of the welds, it will be noticed as the bronze becomes heated, and especially if the bronze is rich in tin, that brilliant globules collect on the surface of the metal similar to the molten drops of lead produced by the white cone of the oxy-acetylene torch.

This phenomenon, which becomes very distinct when the bronze reaches a temperature in the neighborhood of 1,200° F. (650° C.), continues until the alloy melts freely. It may be prolonged for a long time by using a flame much too feeble for melting normally the thickness dealt with.

In this case, as soon as the bronze is at a red heat, the brilliant globules remain on the surface of the metal for a very long time, the surface of the metal remaining solid. These globules of molten metal are sometimes volatilized by the blowpipe and leave on the surface of the metal traces of slag.

Again, if a microscopic examination is made of a bronze from the surface of which beads or globules have been observed to disappear, it will be found that the constituent of the alloy rich in tin has disappeared from the surface.

Before the melting of bronze takes place there is a veritable segregation, which impoverishes the tin in the superficial zone of the alloy. This latter, as a result always has very distinct cavities.

A series of tests has been made on worn bronze bearings built up by the blowpipe. On breaking these bearings across the built-up portions this superficial segregation is very often clearly seen. In fact, below the face attacked by the blowpipe, the reddish color of the break indicates a lowering in the percentage of tin. It follows that a weld, or a building up of bronze, done without proper precautions consists of three parts

—the portion of the article which has not been altered by the passage of the torch; a zone impoverished in tin, a layer of unsound metal; lastly, the added material which may be quite sound.

Tempering and Annealing Bronzes

The annealing of bronzes gives them a uniform constitution, but considerably increases the hardness of the metal. On the other hand, the tempering of bronzes in cold water ameliorates very clearly the mechanical properties of the alloy.

But if it is a question of recharging worn bearings, the tempering in cold water, preceded by a reheating, enables the temperature of the whole article to be rendered uniform. Plunging a bearing into cold water immediately after repair, knowing that the bronzes are not such good conductors of heat as copper, means that only the part rebuilt is submitted to the effects of tempering. This produces a softening effect, whilst the remainder of the piece which has not been re-heated to a temperature sufficient for tempering, retains on the contrary its hardness.

In every case we recommend the uniform annealing of bronze parts, and the tempering after annealing wherever this is possible, for giving homogeneity. It is also very advisable to submit to this treatment bells repaired by welding, the original tone being obtained by the correct reheating.

Execution of Bronze Welds. Preparation of Parts

The edges to be joined should be bevelled in the same manner as that indicated for welding brass, and should be carefully cleaned. In order to avoid the collapse of the metal as it nears its melting point, it is very important, wherever possible, to support the lines of welding and their immediate neighborhood.

It is also necessary to avoid moving large bronze articles after they have been preheated. Articles that have been preheated should be moved with the same care as is necessary when dealing with aluminum castings that have been preheated before welding.

In welding bronze the part to be welded should never project or overhang because the low tenacity of the metal when near the melting point will produce, under the simple effect of gravity, the collapse of the whole of the heated portion.

The size of torch tip to use is the same as that which should be used for welding brasses.

Execution of the Weld

Where the articles to be welded have not been uniformly preheated it is necessary to heat the surrounding portions of the weld, taking care not to bring the white cone of the flame too near the surface of the metal. Too great a localization of the heat leads to the segregation of the tin, as previously explained.

The neighborhood of the weld being at a red heat, heat the welding rod in the zone of the flame and coat with a thin layer of flux, then by bringing the white cone briskly to the surface of the piece, produce simultaneous melting of the welding rod and the piece. Throughout the whole of the welding operation care must be taken not to allow the white cone to come into contact with the molten metal.

Before commencing to weld, the bevelled faces should be cleaned, by means of a metallic brush, of cinders and scale which tend to accumulate during preheating

The welding rod and flux should be applied very regularly, so that the reducing agents which they contain can be diffused throughout the molten metal.

The welds should be executed rapidly and should not be remelted without a new addition of welding rod and flux.

The welds on bronze are generally of a short length so that the effects of contraction are practically negligible.

Flux

To obtain sound welds a flux is indispensable. The flux used in the welding of brasses also gives excellent results in cleaning the surfaces and producing sound joints on bronzes. It is only necessary to dip the welding rod, from time to time, in the flux, to obtain a molten bath perfectly sound.

Treatment After Welding

Certain welders hammer bronze pieces after repair. We consider this operation injurious because, although the hammering increases the hardness of the alloy, it gives it a very high fragility.

It is good to submit the articles to annealing, followed or not by tempering, according to whether the work is required to be hard or, on the contrary, soft.

Applications

Oxy-acetylene welds on bronze executed in a proper manner and with the correct filling materials are highly satisfactory. The repair of bells has been successfully developed and the method of carrying out such repairs will be of interest. If the crack has developed as the result of the shock of the clapper, the repair, as a rule, is a simple one, because the crack extends down to the edge of the bell. If, on the other hand, cracks are set up as a result of the degradation of the metal, the cracks usually radiate in the body and consequently are more difficult to repair.

More commonly the repair is of the former type and the method of procedure is as follows: The crack is bevelled in the usual way and any further extension into the body is prevented by drilling a hole beyond (about ¾ inch) and in the direction of the crack.

By means of a chisel or file the edges of the weld are cleaned. The bell is next heated on a fire (charcoal fire by preference) to a red heat, the bell being arranged so that the welding operation can be carried out without displacing it.

The operation of welding is carried out with a torch flame sufficiently powerful to weld rapidly, taking care not to allow the white cone of the flame to come into contact with the metal and avoiding re-melting. The line of welding is slightly surcharged because the surface sometimes shows small blowholes.

The bell should be allowed to cool as slowly as possible and the weld after cleaning up should not be visible.

If the repair is carried out on these lines, the sonorousness of the bell as when new is obtained, and if the same tone is required as when new, this can be obtained by a reheating followed by tempering in cold water.*

The Welding of Aluminum Bronzes

So-called "aluminum bronzes" are alloys of copper with aluminum, in which the former metal preponderates. The alloys containing 10 per cent of aluminum downwards are those generally manufactured, and of these the 10 per cent alloy is perhaps the best for all-round properties. This alloy is extremely resistant to sea water corrosion and alloys of this type can be exposed to a red heat in an oxidizing atmosphere for several days without becoming appreciably tarnished by oxidization.

These bronzes can be welded perfectly by the torch. It is only necessary to use an energetic flux of the nature of the one used in the welding of aluminum, and a welding rod of practically the same composition as the material to be welded.

**See also under "Bells"*

OXY-ACETYLENE WELDING MACHINES*

Machine welding has been successfully applied to the manufacture of tubing, barrels and other containers. To the manufacturer of a product requiring thin gauge tubing of various sizes, tube welding machinery and fabricating equipment are indispensable. With it he can produce any desired diameter and gauge within certain limits on short notice from commercial sheets, thus avoiding the necessity of carrying a widely diversified stock of tubing furnished from the mills.

Tube Welding Machines—The equipment required comprises gang slitters for cutting sheets into strips of the necessary width, tube welding machines, tube straightening machines, tube grinders, cutting off saws and perhaps tube bending machines. If a smooth highly-finished tube is required, a drawbench may be needed for drawing down. Taper tubes are made by swaging straight tubes, using rotary swaging machines.

A tube welding machine is essentially simple comprising sets of rolls for holding the formed tube beneath the welding torch with means for holding the seam directly under the flame and with the rolls so disposed as to squeeze the fused metal and complete the weld by compression. The speed must be adjusted very closely to the torch power; if the speed is too fast the weld will be incomplete, and if too slow the metal will liquify and enter the spheroidal state, producing holes in the joint. Hence the big problem in designing a tube welding machine is to provide a driving mechanism that can be instantly adjusted to exactly the required speed. The operator should also be able to start, stop and reverse the machine without distracting his attention from the welding operation. Feed control characteristics outlined in the foregoing are secured in one make of welding machine with electric drive using an adjustable speed direct current motor with field rheostat, magnetic control panel and push button station with start, stop and reverse buttons. The speed range is ample for all gauges and diameters from No. 10 to No. 22, provision being made for 36 speeds. The three principal features in tube welding machines are: design and control of the torch, form, position and number of feed rolls and adjustable driving speed, instantly variable between limits.

Naturally, the manufacturer contemplating tube welding is interested in the speed of production. The oxy-acetylene process of welding is limited in speed by the size of the torch tip and number of heating flames. Almost any speed of welding ever required can be accomplished by using torches of the required power, but practical considerations have, up to the present, restricted welding to speeds from say 3 to 15 feet per minute, depending on the gauge and diameter of the tubing.

Welding a tube in itself is only a part of the proposition. The material must be trimmed exactly to the width required for the desired tube diameter and the forming of the flat strip is an operation that can be so mismanaged that the resulting welded tube is a failure. Following operations also require the use of improved machinery operated by men of some skill and experience.

Square, hexagonal, oval and special shapes are generally formed to circular cross-section and welded, the desired shape being produced by drawing through roller dies over a mandrel. Windshield tubing used in such large quantities for motor cars is formed to the required shape and welded at the bottom of the slot in which the glass is set.

Container Welding Equipment—Barrel welding also requires for success that the sheets be properly prepared. Welding is done without filling rod, and expansion and contraction are taken care of by trimming the abutting edges slightly concave so that the expansion of the metal under the torch brings the edges in the center zone together by the time the torch has traveled that far. The cooling of the metal behind the torch then tends to compensate for the local expansion, the result being that when the seam is finished, expansion and contraction have been taken care of and the welded seam lies flat. The degree of concavity required depends on the thickness of the metal and speed of welding.

The growing use of steel drums for gasoline, oils, paints and other liquids due to the scarcity of lumber suitable for making wooden barrels to say nothing of their insecurity and danger, indicate that machine welding should grow in importance as manufacturers become converted to the practicability of the machine process.

Containers for white lead offer a good example for machine welding. The economy of welding containers made from sheets cut to size and shape, over similar containers punched and drawn with presses is considerable. Wastage of stock is reduced to a minimum and the cost of the welding operation is less than drawing, considering overhead due to the large investment in presses and dies.

Container welding is a comparatively simple proposition. The machines designed for one size of container only do not require means for varying the speed within wide limits and when the speed is once adjusted they can be operated day in and day out without change.

Cases for storage batteries are welded successfully with machines so designed that the machine automatically shifts the direction of the welding path thus turning corners without interruption.

Another application of container welding somewhat out of the ordinary is found in the manufacture of steel bottles for carrying hot or cold drinks. These are not vacuum bottles although they are made up with an inner and outer shell. The space between is filled with an insulator of high efficiency nearly equal to a vacuum.

Machine Torches—A limitation of machine welding has been overheating of the torch and consequent flashbacks. Water-cooling of the tip and torch body has been so developed that the torch may be maintained at a uniform temperature and flashbacks eliminated. The larger the tip and the greater the number of flames the greater the necessity for water-cooling. It is highly important that there be no interruption of the flow of water through the torch during the welding operation.

In this connection it is interesting to note that a hand torch has recently been placed on the market with extension tubes so designed that the refrigerating effect of the escaping acetylene and oxygen cool the metal of the tube and tip to such temperature that the flashbacks cannot enter and follow back to the mixing chamber. The principle is that of conveying the mixed gases through copper extension tubes of small diameter. The refrigerating effect of the expanded gases reduces the temperature of the tube to such a degree that an incipient flashback is immediately extinguished. A small diameter copper tube with brightly polished surface absorbs less heat from the hot metal and the refrigerating effect of the expanded gases is proportionately greater than with tips of the usual size.

**Extract from a paper read before the International Acetylene Association, by Fred E. Rogers, with additions by the editors.*

Weight Saving Made Possible by Machine Welding—An example of aplication of the semi-automatic type of machine welder is found in steam radiator sections. The ordinary cast iron radiator section used in houses is objectionable in large office buildings partly on account of its bulk and chiefly because of the weight. Architects find that the weight of the heating equipment in a multi-story building is an item of serious consideration in the total floor load. If the weight of the radiators can be reduced two-thirds it means a very substantial decrease in cost of the steel frame and floors. But to make steel shell radiator sections by hand welding is not to be considered if it can be done at less cost by machine. Such parts can be economically welded by machinery and at a rapid rate.

Welding Fixtures—This brings before the attention of the manufacturer the general subject of jig and fixture welding for production work. Small parts must be held in suitable frames while under the welding torch, leaving the operator free to operate the machine, remove the welded pieces and replace the unwelded ones.

Duograph

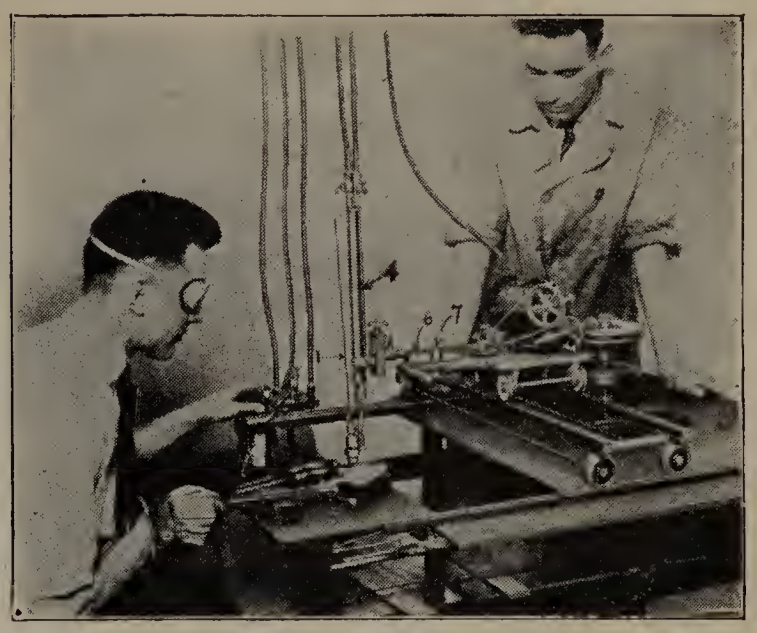
The Duograph is a manufacturing machine designed for production welding of steel boilers, tanks and containers. Steel shells formed to cylindrical or rectangular shape are placed on a horizontal water-cooled welding arm and held by clamps while the torch is traversed along the seam by power. One torch only is used on thin gauge metals, but the machine provides for two torches, one above and one below when working on heavy gauge containers. Two work-holding arms stand opposite and are mounted on a pivot forming a turret fixture which is loaded and unloaded at one station and welded at the other.

Weldograph

The Weldograph is a motor-driven oxy-acetylene welding machine designed for welding sheet metal parts manufactured in quantities. It is adaptable to a wide range of products, such as steam and hot water radiators, mufflers, motor car parts, metal boxes, and many novelties. One form discharges the work when the weld is completed and the other forms propel the work under the flame while held in jigs.

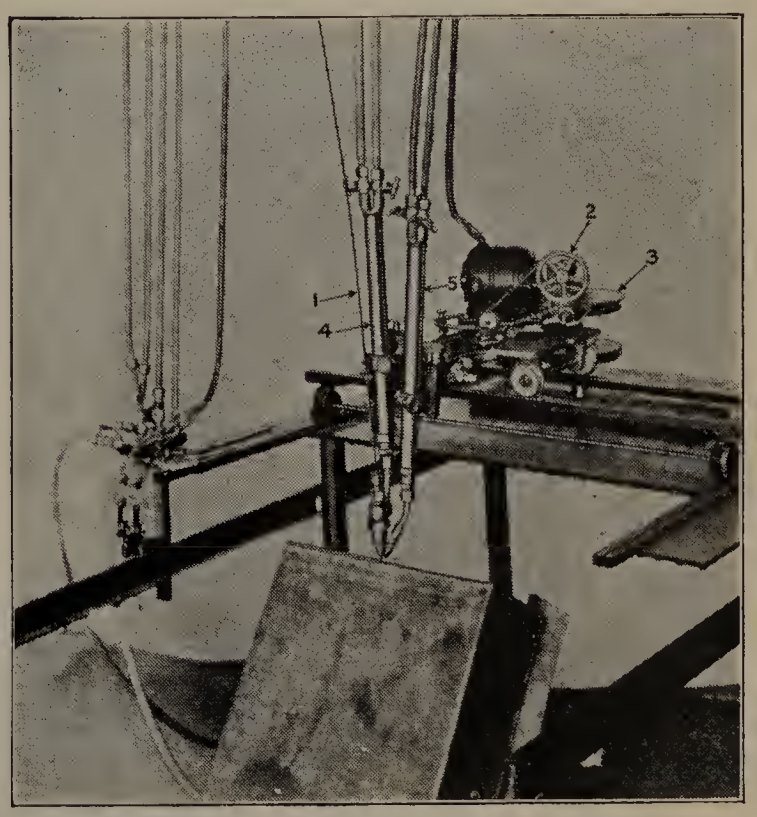
Gewe Automatic Welding Machine

This machine is a motor-driven, self-feeding oxy-acetylene torch. The welding wire is fed by gravity through the center of a multiple-flame. The machine is mounted on a double carriage system, so that it follows irregular welding lines by means of patterns and special drives. A spiral motion is given to the welding wire and the spot in fusion is kept surrounded by flames while in a molten state. For heavy welding a special type of machine is made, which has two torches. One torch moves steadily



Gewe Automatic Welder

over the center of the seam to be welded, preceding the self-feeding welding torch, so as to preheat the seam to very near the fusion point. The welding torch is moved



Gewe Heavy Duty Automatic Welder

forward with a slight circular motion so as to melt not only the seam proper but also both sides of the seam, spreading the added material over the same area.

THERMIT WELDING*

The Thermit Reaction

THE Thermit Process is based on a chemical reaction between aluminum and iron oxide. Such a mixture (Thermit) can be ignited when brought to a high temperature in one spot and the reaction when so started will continue throughout the rest of the mass, the result being that the aluminum combines with the oxygen of the iron oxide to form aluminum oxide (or slag) in a highly super-heated molten state while the iron is set free and is produced as liquid steel, also highly super-heated. The temperature of this reaction is not measurable by any mechanical instrument, but it has been determined theoretically by metallurgists as approximately 5,000 degrees Fahr., or almost twice the temperature of ordinary liquid steel. It can readily be seen that if steel at this high temperature be poured around and between two iron or steel sections, which have been previously heated to red heat, they will become dissolved and will amalgamate with the Thermit steel so that finally the entire mass will cool down to form a single homogeneous section.

There is absolutely nothing explosive about the Thermit reaction and no danger is incurred in storing and handling the material, owing to the fact that it requires the temperature of liquid steel to ignite it.

Cutting Out Fracture

It is desirable to place tram marks on the two sections to be welded at points outside of the mold box to gauge the allowance to be made for the contraction of the Thermit steel when it cools. Then cut out the metal along the line of the fracture so that an opening is provided according to the table of welding portions, the amount of the opening depending on the size of the sections to be welded.

There are two ways of cutting out this metal, the latest and best method being to employ a cutting flame of acetylene gas and oxygen. If this method is not available a series of holes may be drilled along the line of the break and afterward all metal between the holes removed so as to make a clean opening for a free flow of Thermit steel between the sections to be welded together. If the fracture runs diagonally it is advisable, when cutting out, to make the opening as nearly vertical as possible.

Clean Sections

Next clean the sections thoroughly for a space of at least 5 in. so as to expose good bright metal on each side of the fracture. Be sure to remove all dirt and grease as far back as the mold box will reach so that when the mold is rammed and the heat applied there will be no grease to burn out and leave a space between the mold and the parts to be welded. **If oxy-acteylene is used for the cutting, be sure to remove all oxide and scale left on the parts from the cutting operation.**

Allowance for Contraction

Next make the allowance for contraction by setting the parts away from each other a sufficient amount to make up for the contraction of the Thermit steel in cooling. This should be varied from $\frac{3}{16}$ in. to $\frac{5}{16}$ in., depending on the size of the weld and the length of the time of preheat. In many cases it is necessary to obtain this increased space by forcing the sections apart with a jack or other mechanical means. In other cases such as the welding of a double-barred locomotive frame it will be necessary to heat an opposite member by means of a flaming burner attachment or the Thermit double burner preheater. It is sometimes advisable to construct a small fire brick or sheet iron furnace around such a section in order to confine the heat or protect other parts from the flame. This, however, is done only at time of preheating. Care should be

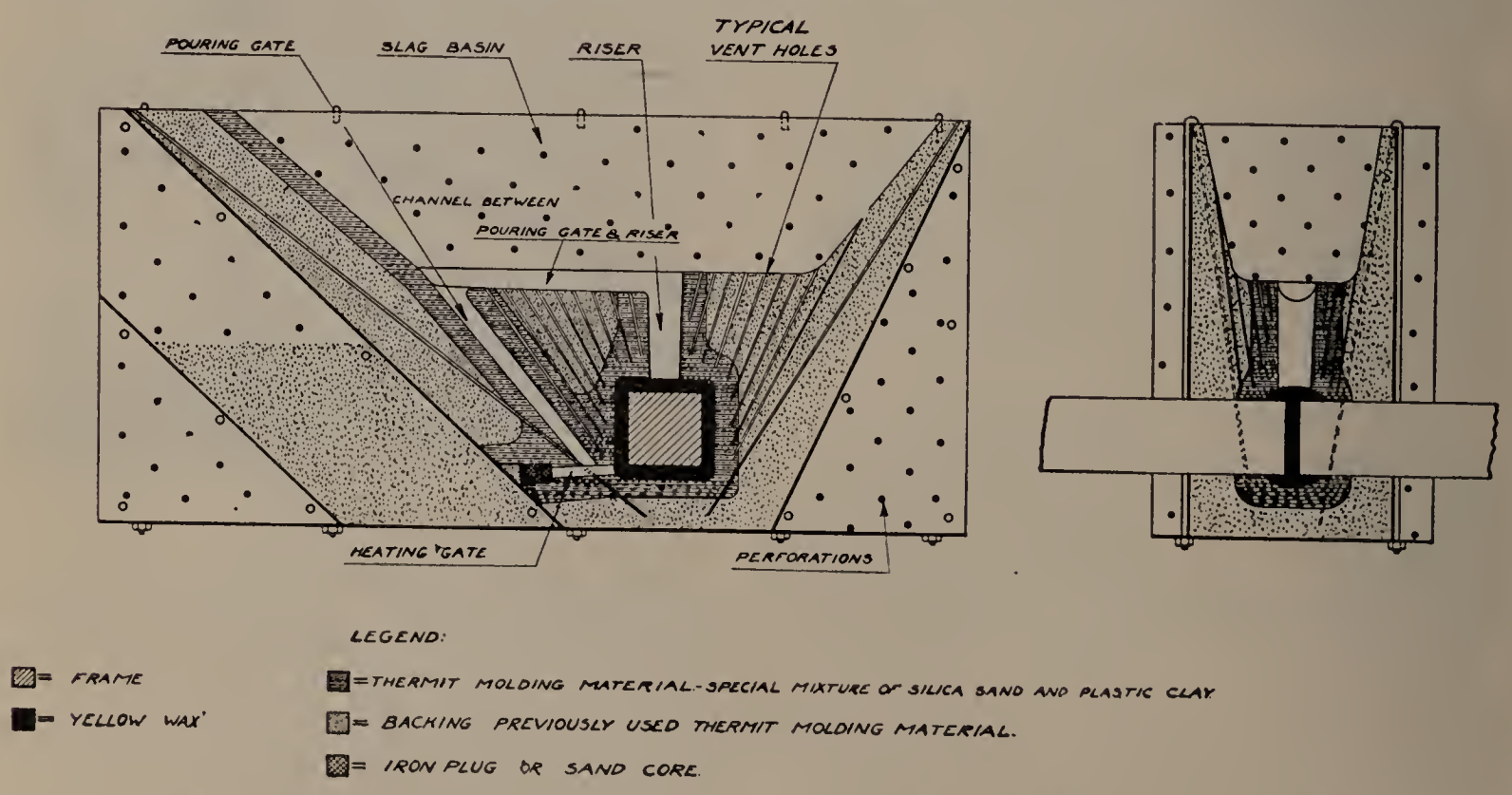


Fig. 1.—Method and Materials Used in Constructing Molds for Thermit Welds.

*Written for The Welding Encyclopedia by W. R. Hulbert and L. I. Grinnell.

taken not to heat too hot for expansion or the metal will upset. A black heat is usually sufficient.

Wax Pattern

The parts are now ready for the pattern, which is made of yellow wax.

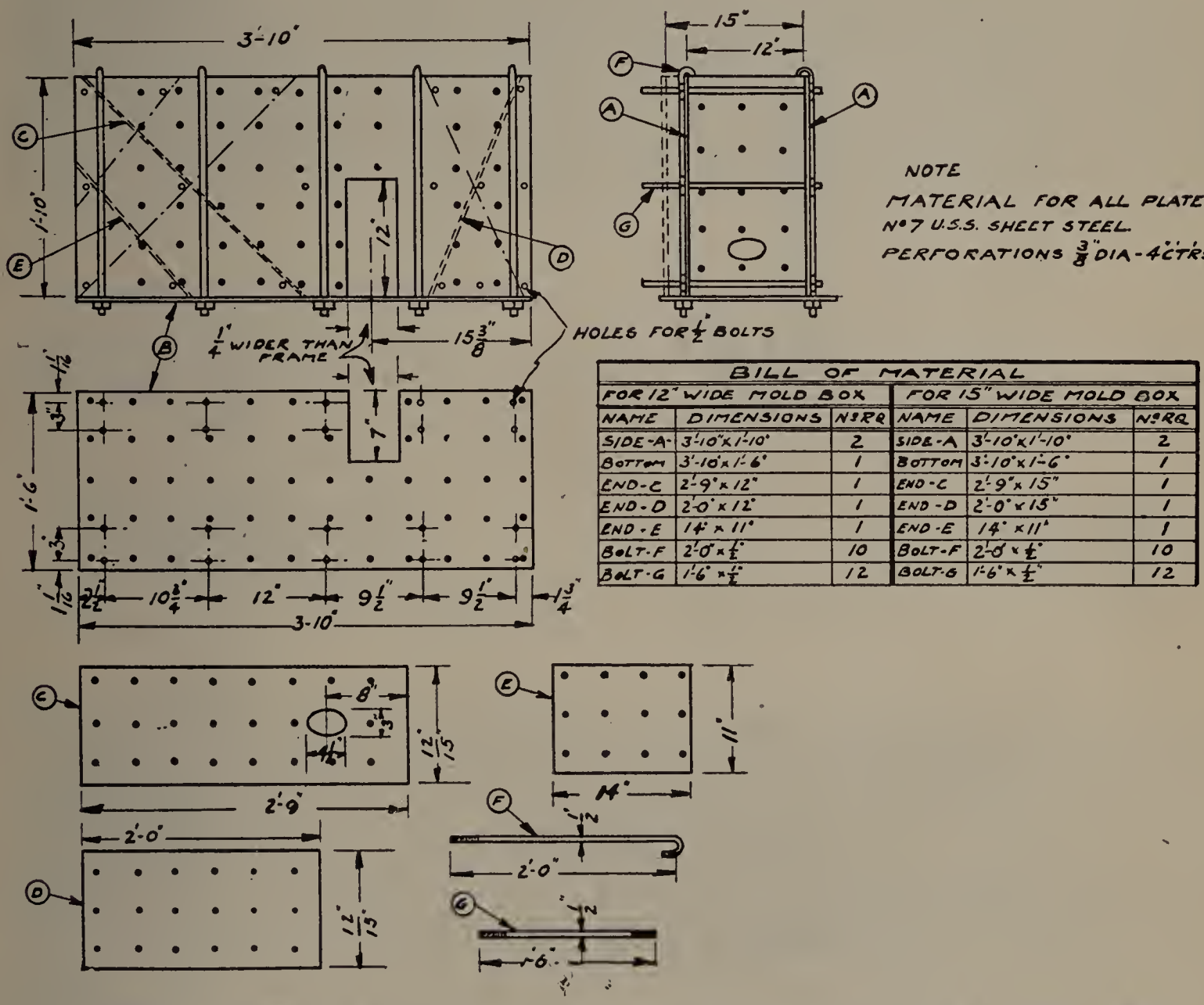
This wax should be placed in a pan and warmed until it becomes plastic, or better melted entirely and then allowed to cool until it becomes plastic. This is shaped around the parts to be welded in the form of a collar as shown in Fig. 1. The opening between the ends should also be filled with wax and it is necessary to provide a vent hole through the wax extending from the location of the heating gate to the riser. A convenient way to do this is to bore a hole with a hot rod from the heating gate to the riser. Plug these holes with waste while ramming the mold.

Mold Box

The mold box with perforated sides and bottom should then be placed in position and securely blocked up so that all weight will be removed from the sections to be welded. Fig. 2 shows the proper design for a mold box.

We are now ready for the molding material. The selection of a proper molding material is probably one of the most important parts of the entire thermit welding operation, as upon this depends to a great extent the soundness of the weld. After a great deal of research, The Metal & Thermit Corporation developed a molding material which exhibits both the necessary refractory qualities and the very necessary porosity after preheating. The molding material is composed of the following: 3 parts clean, sharp silica sand (100 per cent of which should pass through a screen having a .03 in. square opening, and 40 per cent of which should be retained on a screen having a .012 in. square opening), mixed with 1 part Welsh Mountain plastic clay. These parts are first thoroughly mixed in the Muller together with 1/40 part glutrin by volume and sufficient water (1/12 part) to bring to the proper consistency. If mixed by hand, the sand and clay must be dried before mixing (being careful not to subject the clay to a temperature higher than 400 deg. Fahr.) and thoroughly mixed before adding the glutrin and water. The glutrin should be mixed with water before adding to the sand and clay.

In case a plastic clay fatter than the Welsh Mountain be used, the mixing, of course, will have to be more thorough and less clay used. Welsh Mountain clay is being used in the present mixture because in carefully run tests it has proved to be the most refractory. The use of the new molding material necessitates harder packing next to the weld; in fact, the regular Thermit rammer may be supplemented by the



BILL OF MATERIAL

FOR 12" WIDE MOLD BOX			FOR 15" WIDE MOLD BOX		
NAME	DIMENSIONS	No RQ	NAME	DIMENSIONS	No RQ
SIDE-A	3'-10"x1'-10"	2	SIDE-A	3'-10"x1'-10"	2
BOTTOM	3'-10"x1'-6"	1	BOTTOM	3'-10"x1'-6"	1
END-C	2'-9"x12"	1	END-C	2'-9"x15"	1
END-D	2'-0"x12"	1	END-D	2'-0"x15"	1
END-E	14"x11"	1	END-E	14"x11"	1
BOLT-F	2'-0"x 1/2"	10	BOLT-F	2'-0"x 1/2"	10
BOLT-G	1'-6"x 1/2"	12	BOLT-G	1'-6"x 1/2"	12

Fig. 2.—Design and Materials Required for Standard Mold Box in Making Thermit Welds on Locomotive Frame Sections Up to 6½ in. x 8 in. in Size. Larger Mold Boxes Can Be Made in Proportion.

The mold box for locomotive frame welds is much longer than for similar sections in general repairs so as to allow the top of the pouring gate and therefore the crucible to be positioned without interfering with running boards, air reservoirs, etc.

use, for instance, of a tool having an end ⅜ in. x 1½ in., so that the operator may be able to peen the sand next to the wax collar and the various patterns.

In one's first thermit welding operations, such a molding material as described above should be used throughout the mold; and, thereafter, this molding material—once used—should be screened, sieved and re-used as backing in subsequent operations. New material should, however, always be used to line or face all portions of the mold with which the thermit steel will come into contact, and it is usual to make this facing about 1 in. or so thick. The molding material should, of course, be moistened to just the proper consistency to make it ram well.

Ramming Mold Box

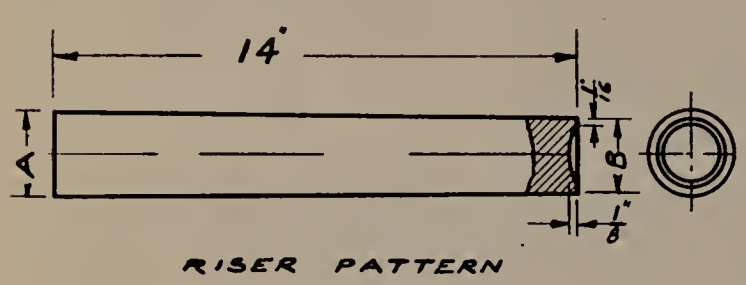
In ramming the mold place a small amount of molding material in the box and ram with a small rammer around the edges and working toward the center, keeping the mold level, and RAM HARD. Too much emphasis cannot be laid on this point, for on the construction of the mold depends the safety of the entire welding operation. See to it that the material is well rammed underneath the pattern and is hard and firm at this point and at all points where it comes in contact with the wax and wooden patterns, and subsequently with the thermit steel. There should be a wall of molding material at least 4 in. and not exceeding 2 ft. in thickness, depending on the size of the sections, between the wax pattern and the mold box at all points, as the Thermit Steel is intensely hot and ample molding material should be provided to hold it.

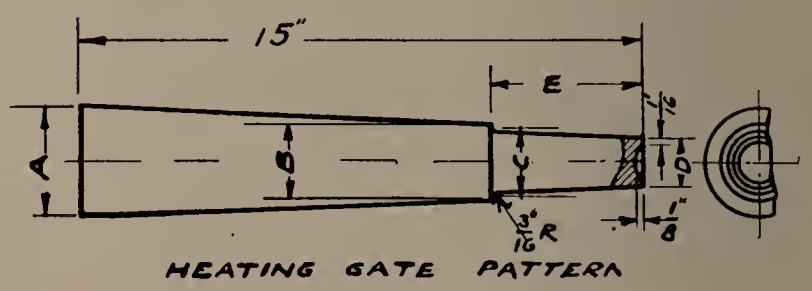
Gate Patterns

A wooden gate pattern for the preheating opening should be set at the lowest point of the wax pattern and leading out to the front of the mold box where an opening is provided for it. Where the sections to be welded together are of the same size this preheating gate should be set directly in the middle of the wax pattern so as to heat both sides equally; sometimes, however, it is necessary to weld a light section to a heavier one in which case the preheating opening should favor the heavier section which will require a longer time to heat than the light section.

With the preheating gate provided for, the pouring gate pattern is placed against it and the junction of these two located about midway between the wax pattern and the shoulder on the heating gate. If these two wooden patterns are caused to fit neatly together, there will be less work later in removing the fin of sand at this junction point, as it is important that all points of the interior of the mold and gates be hard, firm and smooth without projecting fins or ledges in the sand which might break off and be trapped in the thermit steel.

Different operators adopt different "kinks" in ramming the mold, but the usual way is to ram backing up to or a little above the bottom of the wax collar, then trowel out the 1 in. space next to the wax collar where the facing should be and ram this hard with facing. In the same way, the backing and facing are rammed hard to a point above where the heating gate will be and a channel troweled out for the heating gate to lie in, and the heating gate pattern then pounded or tapped down with the rammer until it has sunk into the molding material to its proper position. More facing is then rammed on top of this heating gate—completely burying it; and on either side of this, more backing rammed even against the wax collar itself. When a depth of 2 in. or 3 in. above the heating gate has been reached, the 1 in. or so next to the wax collar is again troweled out and facing put in and rammed hard. In a similar way, a round hole is dug down to expose the top of the heating gate pattern, an inch or more away from the wax collar; the pouring gate pattern carefully placed, and the space around the pouring gate then filled up with facing to the level to which the mold has already been rammed. This method of ramming in backing and cutting away those portions where it must be replaced with facing is then followed until the mold is completely filled, the riser pattern placed in practically the same manner as was the pouring gate pattern, and the top of the mold hollowed out to form a basin, as will be described in more detail later.





SIZE	A	B
No 1	1¾"	1½"
No 2	2¼"	2"
No 3	3¼"	3"

SIZE	A	B	C	D	E
No 1	2½"	1½"	1⅛"	1"	3"
No 2	2¾"	1¾"	1⅜"	1¼"	4"
No 3	3"	2"	1⅝"	1½"	5"

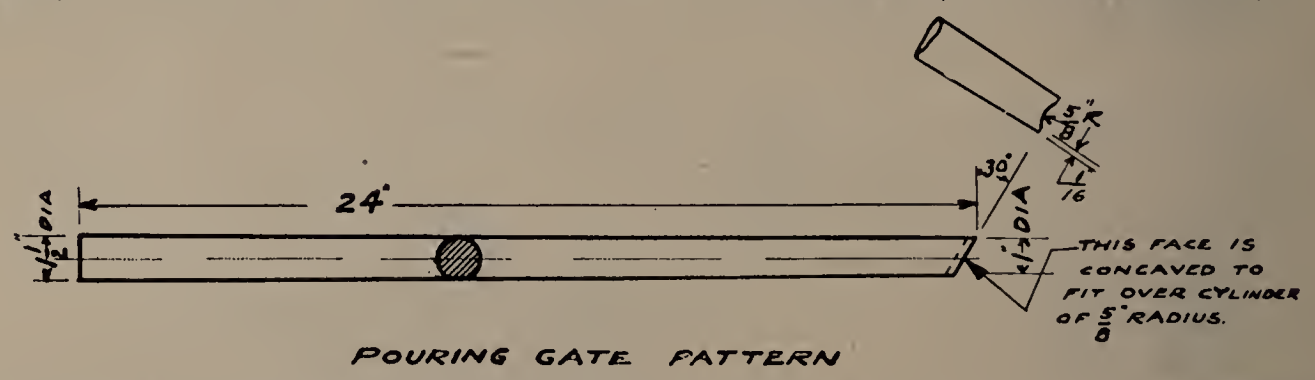


Fig. 3.—Wooden Patterns for Pouring Gate, Riser and Heating Gate of Mold. These Are Large Enough for Welds Up to 6½ in. x 8 in. in Size.. Proportionally Larger Patterns Are Required for Welds of Greater Size.

Riser

At the highest point of the wax pattern

place the riser pattern. If there is more than one high point, place a riser pattern over each as the function of a riser is to hold a supply of steel which will remain liquid for a considerable period of time and take care of all shrinkage so that when a pipe is formed due to shrinkage, this pipe will appear in the riser and not in the weld. Also the riser acts as a depository for loose sand or other foreign matter which may be washed into it by the Thermit steel in passing through the mold and prevents this material from clogging in the weld. It sometimes happens that welds are made at a point where a wooden riser pattern cannot be withdrawn conveniently. In such a case, a piece of jacket iron pipe (but surely not copper, tin, or galvanized pipe, etc.), may be used and left in the mold after ramming.

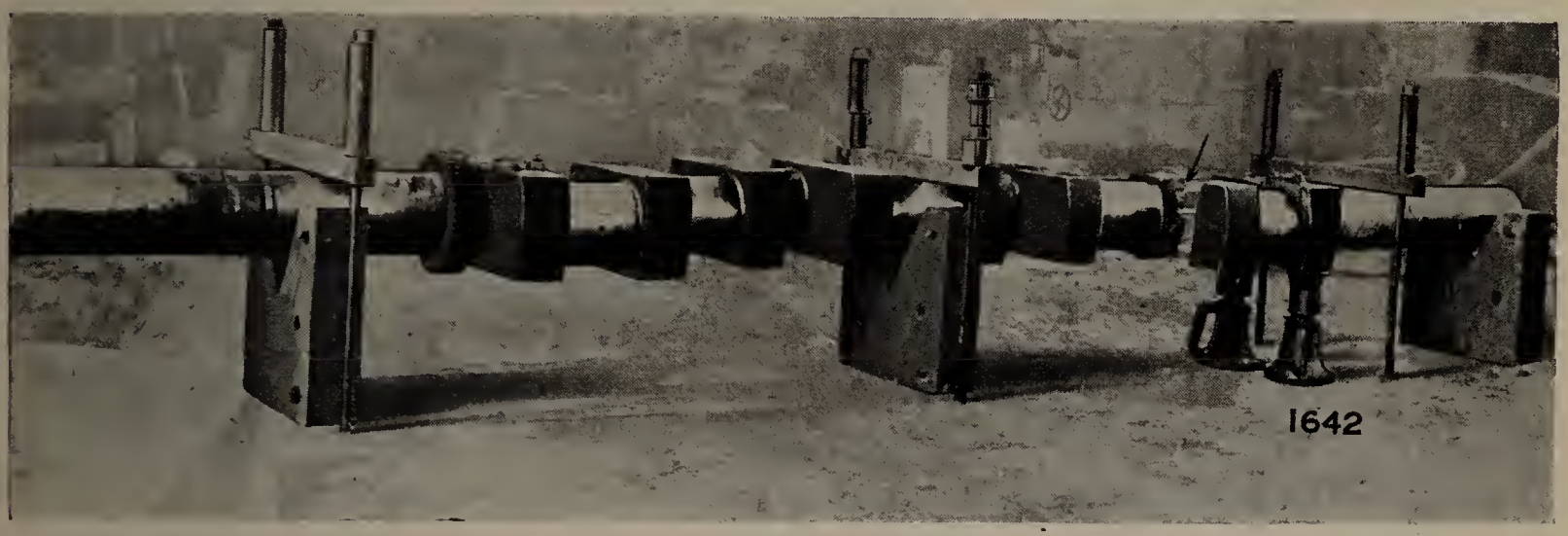


Fig. 4.—Crankshaft Fracture in Crank Web Cut Out Ready for Weld.

Riser for Vertical Welds

In the case of vertical welds, i. e., welds in which the axis of the two pieces is vertical and the plane of the weld horizontal, care should be taken in cutting out the fracture and in placing the risers so that no gases, slag or sand will be trapped in the weld. It has not been found advisable to place any of these risers directly up against the section at the upper edge of the collar because this reservoir of heat so close to the section is liable to melt the section away above the weld, and yet when the risers are placed ¼ in. or more down from the top edge of the collar it is evident that there will be a pocket above the level of the base of the riser in which air will be trapped when the mold is filling rapidly with steel. Therefore, it is very important that this extreme top edge of the collar all the way around the section should be completely vented to the top of the mold so as to allow the air to escape freely as the mold is filling.

Many operators have found it advisable to lay in alongside of the section, thin wooden shims, 1/16 in. to ⅛ in. thick, which are withdrawn after the mold is rammed and therefore completely vent the top edge of this collar all the way around. It is true that this space will be filled with steel, but the fin will be so small that it will chill against the frame and not weld to it and, therefore, can be readily chipped off upon completion of the weld.

Fig. 5.—Crankshaft Welded.

Venting of Mold

After the mold is all rammed hollow out on top so as to form a basin for the slag to collect in and not overflow the mold box. Cut a channel or trough in the top surface of the mold, connecting the top of the pouring gate and the top of the riser so as to cause the first slag overflowing on top of the mold to quickly run across to the riser and thus while the metal is still very liquid, equalize the pressure on the pouring gate and the riser. Then vent the mold thoroughly by forcing a vent rod made from 8 gauge or 10 gauge steel wire down through the molding material to within 3 in. or 4 in. of the bottom. Be careful that the vent holes do not touch the wax collar or the gates, otherwise the vent holes will fill with steel and will therefore, be useless as a vent. These vents should be as numerous as practical and some of them, possibly larger than the rest, should be carried up to each of the top corners of the mold box where they will continue to stay open even after the slag has completely filled the basin on top of the mold. The purpose of these vents is, of course, to allow the escape through the mold of any air which may have been trapped in the falling steel and any gases formed in the mold on account of the high temperature of this liquid steel.

Adjust Crucible

Now rap lightly the gate, riser and heating opening patterns and draw them out carefully, wiping away any loose sand that might tend to fall into the holes. It is best to use a molder's lifter for this purpose. After the pouring gate and heating gate patterns have been removed, slick off carefully any sharp edges or fins at the top of the pouring gate and at the junction of the pouring and heating gates. This latter point can best be reached by means of a ¼ in. rod slightly curved at its end. After preheating, the sharp edges and fins at the junction of the heating gate and wax collar and at the base of the riser can be similarly slicked off.

Preheat

The mold is now ready for preheating. Set the burner of the Thermit preheater so as to point into the heating gate of the mold and about one inch from the opening. Then apply the blast. It is best to start easily at first as too much of a blast would tend to cut the mold. The wax will burn out leaving a perfect mold just the shape of the wax pattern. Cover the various openings on the top of the mold so that nothing can fall into them, and then proceed to plug and charge the crucible as instructed in the next paragraph, doing this promptly so that there will be ample time to lift it into position with its charge, adjust it properly with the bottom about 3 in. above and directly over the center of the pouring gate, and support it firmly. If the crucible cannot be placed directly over the pouring gate, construct a runner, as shown in Fig. 11, to lead the steel into the pouring gate. Keep the heat going until the mold is thoroughly dried out and the parts to be welded are brought up to a good workable heat such as would be required if the parts were to be hammered.

While the preheating is in progress, and having made sure that the crucible has been thoroughly dried out and possibly even still warm from this drying operation, the

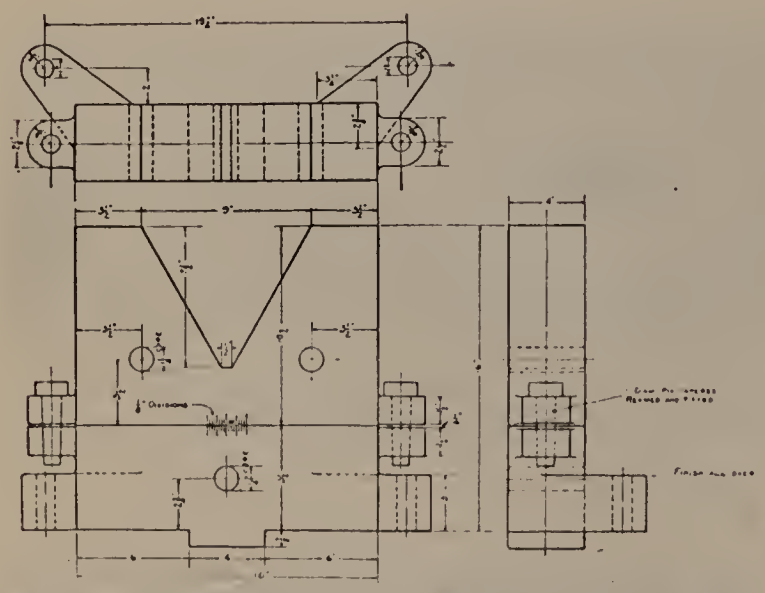


Fig. 6.—Showing Proper Design for V Blocks for Thermit Welding Crank Shaft.

charge of Charge Crucible Thermit and additions should be placed in the crucible which is first plugged in accordance with the directions given later. Each bag of thermit should be thoroughly mixed by dumping it into a pan and turning the pile over a number of times before dumping it into the crucible. The thermit cannot be properly mixed after dumping it into the crucible. **It is important to put in a few handfuls of Thermit first,** before dumping in the rest of the charge, so as not to disturb the plugging material. Mix the Thermit charge thoroughly before putting in crucible. **No Ignition Powder should be added until the Thermit charge is ready to be ignited.** If the Thermit charge, when leveled off, comes closer than two inches to the top of the crucible, or if the crucible has to be tipped slightly, it is best to build up the crucible by means of a ring. This ring should be slightly less in diameter than the top of the crucible, so that it will set into the crucible to a depth of about one inch. It should be from 8 to 10 inches high and made from

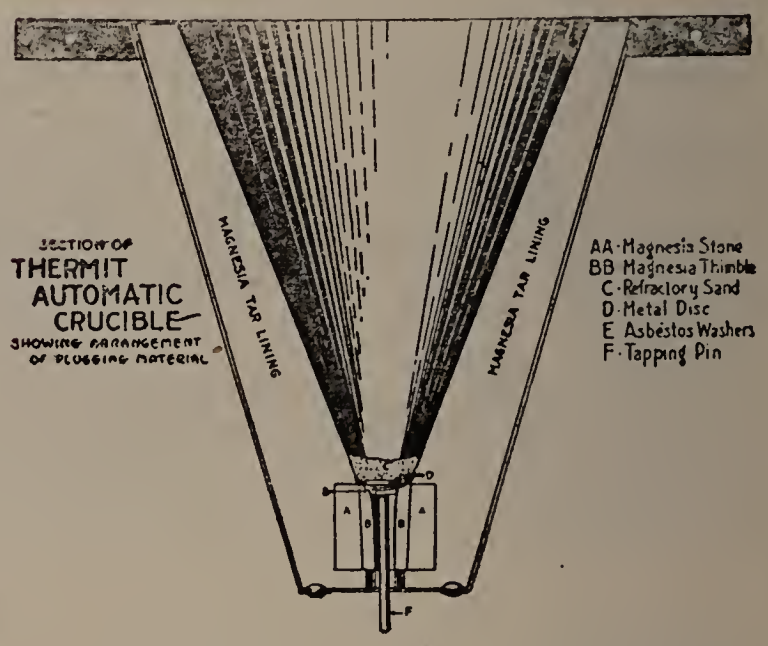


Fig. 7.

¼-inch stock. Lute with fireclay between the ring and the crucible.

Too rich a flame during the early part of preheating may not be harmful, but, especially toward the end, see that no excess oil is used so that the lean flame will tend to burn out from the molding material any oil which may have penetrated during the early part of the preheating.

Plug Heating Gate

When it is assured that the sections are at a good workable heat, quickly remove the burner and direct it down the riser so as to blow out any sand or dirt which may be in the mold. If the riser is difficult to get at, direct the burner down the pouring gate. Examine as carefully as possible the interior of the mold to locate any possible loose sand particles and be sure that these are blown out before the heating gate is plugged. Then plug the preheating hole with a sand core or an iron plug. If an iron plug is used, be sure that it is clean and not rusted, tin, galvanized, etc. Many operators make these sand cores by wrapping a piece of heavy paper around the proper part of the heating gate pattern, sliding this off carefully and then ramming thermit molding material into the form so made and baking slowly and carefully over the mold during preheating.

Whatever form of plug is used, it should be heated slightly before using to be sure that it is thoroughly dry, then the plug should be placed carefully into position, being sure that the subsequent backing up of the plug cannot force it by the shoulder in the heating gate and thus possibly interfere with the bottom of the pouring gate. A short plug will do, but it should fit neatly in the heating gate. Such a short plug could then be backed up with molding material, lightly tamped into the heating gate, and this in turn backed up with several shovelsful of molding material rammed in between the mold box and the steel plate provided for the purpose. This will prevent any possibility of the Thermit steel running out through the preheating opening. **All heating apparatus should be removed to a safe distance, while the Thermit reaction is in progress.** Occasionally, on account of moisture in the crucible lining or in the thermit

itself, there will be some splashing out of slag from the crucible during the reaction, and it is well therefore, to see that the riser and any other openings than the pouring gate are covered with small pieces of sheet iron to prevent this slag by any chance from dropping into the mold and adhering to the sections to be welded.

Ignite Thermit

Mix the contents of the ignition powder can and then place onehalf teaspoonful of Ignition Powder on top of the Thermit in the crucible (Thermit will not ignite from the heat of the preheater and the reaction cannot be started without Ignition Powder). The Ignition Powder can be ignited directly with a match, but as this is more difficult and the sudden flare liable to burn the operator's fingers, it is preferable to partly bury the head of the match or use a thin iron rod heated red hot over the top of the mold. It is important that ample time be allowed for the completion of the reaction. The crucible should be tapped when it is heard that the reaction is over, which usually takes from 25 to 35 seconds. The operator can very easily hear when the reaction has quieted down. This is accomplished by knocking up the tapping pin which sets in the bottom of the crucible, using for the purpose the tapping spade or a flat piece of iron 1½ in. x ¼ in. x 4 ft. long.

Hold Up Expansion

It is important, of course, that the expansion previously obtained should be maintained until the weld has solidified sufficiently to enable it to resist the tendency of the frame to crush it. On the other hand, it is probably even more dangerous to resist the shrinkage of the metal in the weld during solidification, so that the operator should use careful judgment in this matter. It has been found that usually a locomotive frame weld, although still at a good red heat after half an hour, nevertheless is sufficiently strong and solid to take this pressure after half an hour if the pressure is not applied too suddenly, so that rather than to take any chance of straining the weld during solidification, the jack should be released carefully after half an hour. The operator, if he cares to watch the tram marks, can readily determine whether the weld is being upset or not: and if not, the jack should, of course, be completely removed.

Where the expansion has been obtained by preheating a parallel member, the preheater can be removed when or shortly after the weld is poured. If properly timed in this way, the two parallel members will contract together nicely. Be sure that the contraction of the weld is not resisted by the jack or otherwise, because at these high temperatures, the weld material has little strength and may be damaged by this resistance.

Leave Mold Overnight

The mold should be allowed to remain in place as long as possible, preferably over night so as to anneal the steel in the weld, but in case of necessity it can be removed after two or three hours in light locomotive frame welds, or about four hours in heavier frame welds.

Remove Gates and Riser

After removing the mold cut off the metal in the riser and pouring gates with a cutting torch, or else drill through these sections and knock them off.

WELDING PORTIONS FOR WELDING LOCOMOTIVE FRAMES

Width of Frame Inches	Depth of Frame Inches	Width of Gap Inches	Width of Thermit Steel Collar Inches	Thickness of Thermit steel collar center Inches	Dia. of Heating Gate Inches	*Dia. of Pouring Gate Inches	Dia. of Riser Inches	Amt. of Thermit Rec. Lbs.
3	2	½	2½	½	1	1	1¼	10
3	2½	9/16	2¾	9/16	1	1	1¼	12
3	3	5/8	3	5/8	1	1	1½	16
3	3½	11/16	3¼	11/16	1	1	1½	20
3	4	¾	3½	¾	1	1	1½	25
4	4	⅞	4	⅞	1¼	1¼	2	40
4	4½	⅞	4	⅞	1¼	1¼	2	45
4	5	⅞	4	⅞	1¼	1¼	2	50
4	5½	1	4½	1	1¼	1¼	2	60
4	6	1	4½	1	1¼	1¼	2	65
4½	4½	1	4½	1	1¼	1¼	2¼	60
4½	5	1	4½	1	1¼	1¼	2¼	65
4½	5½	1⅛	5	1⅛	1¼	1¼	2¼	70
4½	6	1⅛	5	1⅛	1¼	1¼	2¼	75
5	5	1⅛	5	1⅛	1¼	1¼	2½	75
5	5½	1⅛	5	1⅛	1¼	1¼	2½	80
5	6	1¼	5½	1¼	1¼	1¼	2½	85
5	7	1¼	5½	1¼	1¼	1¼	2½	90
5½	5½	1¼	5½	1¼	1¼	1¼	2¾	85
5½	6	1¼	5½	1¼	1¼	1¼	2¾	90
5½	7	1¼	6	1¼	1½	1½	2¾	105
6	6	1¼	6	1¼	1½	1½	3	100
6	6½	1¼	6	1¼	1½	1½	3	115
6	7	1⅜	6½	1⅜	1½	1½	3	125
6½	6½	1⅜	6½	1⅜	1½	1½	3¼	130
6½	7	1⅜	6½	1⅜	1½	1½	3¼	140
6½	8	1⅜	7	1⅜	1½	1½	3¼	150
7	7	1⅜	7	1⅜	1½	1½	3½	150

*Diameters shown above for pouring gates are mean diameters. In practice these pouring gates should be tapered, bottom diameter approximately ¼ in. less and top diameter approximately ¼ in. greater than dimensions given.

1—The portion is based on an angularity of the pouring gate of 45 deg. or less. Where, due to conditions, the pouring gate must be put on a greater angle, it will naturally necessitate a longer gate and the portion should be increased accordingly.

2—The portions given above are tabulated for welds in horizontal sections. Where vertical sections are to be welded, the portion should be increased slightly to allow for the slight veeing of the upper member and the greater number of risers, fins, etc., ordinarily used in vertical welds.

Quantity of Thermit Required

The amount of Thermit needed for welding sections of different sizes can be derived from the accompanying table. These amounts are given on the supposition that the Thermit collar or reinforcement is made in accordance with the dimensions published in the table.

Calculating Thermit for Large Welds

In the case of larger welds it is possible to use a higher percentage of punchings than with smaller welds, as there is enough additional heat to melt these punchings without reducing the temperature of the steel sufficiently to interfere with the weld.

The usual mixture recommended for these large welds is plain Thermit mixed with 20 per cent mild steel punchings. 1 per cent crushed manganese and 1 per cent nickel Thermit, i.e., to every 100 lb. of plain Thermit add 20 lb. of punchings, 1 lb. of manganese and 1 lb. of nickel Thermit. If Railroad Thermit is used, simply add 1¼ lbs. of punchings to each bag.

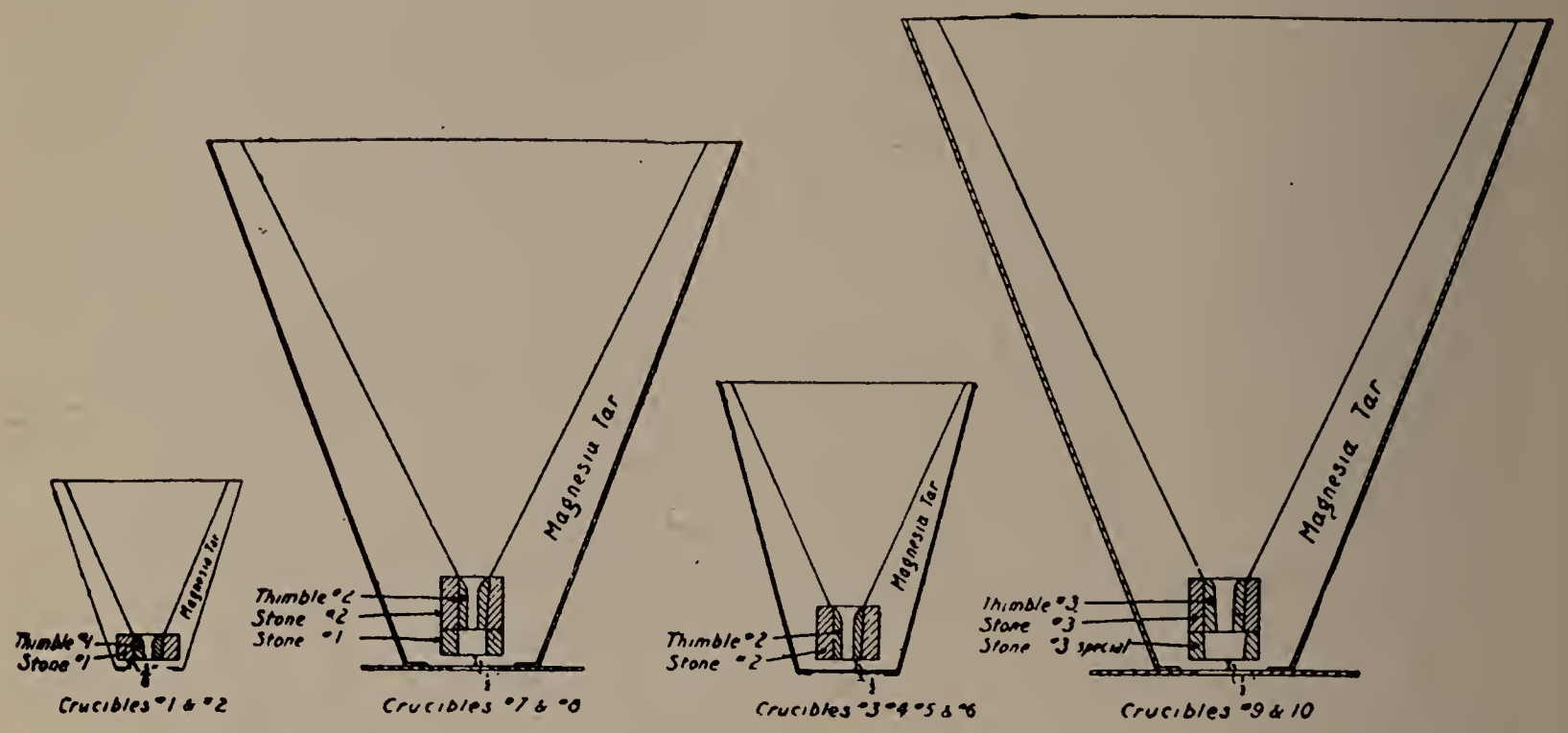


Fig. 8.—Diagrammatic Drawings of Automatic Crucibles, Showing How Two Magnesia Stones Are Used in Some Sizes.

Calculating Thermit from Wax

It is better practice, however, to calculate the amount of Thermit needed for a weld from the weight of wax used in the pattern and it is advisable anyway to make this calculation as a check.

Where the quantity of Thermit is calculated from the wax, great care should be taken to see that the **entire** space which is to be filled with Thermit steel is FILLED WITH WAX so that not only the collar but the space between the sections is filled with wax. Then by weighing the wax before and after completion of this operation, the difference will be the quantity of wax used and for every pound so used allow one bag of Railroad Thermit.

Railroad Thermit

The use of Railroad Thermit is recommended in all cases, as it is ready mixed with the manganese, nickel and steel additions, sufficient to produce 16½ lbs. of high quality thermit steel. The intensity of the heat of the Thermit reaction will be moderated thereby without interfering with the efficiency of the weld. In fact, the quality of the metal will be improved and the amount of carbon in the Thermit steel increased. This has been found to give best results for welding wrought iron and steel. For convenience RAILROAD THERMIT is supplied in waterproof paper bags holding 29 lbs., 5¾ oz. of the mixture so that one bag to the pound of wax is sufficient for a weld. This rule provides ample Thermit steel not only for the weld proper but for the pouring gate and riser.

Calculation for Plain Thermit.

In case the welder has plain Thermit instead of Railroad Thermit on hand he should then allow 25 lb. of plain Thermit to the pound of wax and mix with this plain Thermit 1 per cent pure manganese, 1 per cent nickel Thermit and 15 per cent mild steel punchings, i.e., to every 100 lbs. plain Thermit add 1 lb. of pure manganese, 1 lb. nickel Thermit and 15 lb. mild steel punchings.

Thermit for Special Steels

In special cases, it is advisable to make up a special mixture so as to produce a Thermit steel of essentially the same analysis as the steel in the pinion. The Metal & Thermit Corporation will recommend such special mixtures of Thermit if an analysis of the steel in the pinion is furnished to them.

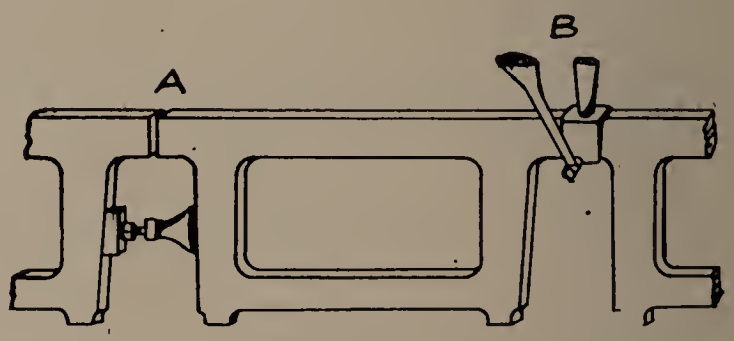


Fig. 9.—Steps in Making a Thermit Locomotive Frame Weld.
A—Gap Cut Out for Entrance of Thermit Steel.
B—Thermit Weld Before Removing Riser and Pouring Gate.

The quantity required for a weld should be calculated from the weight of wax used in the pattern and it is convenient to figure on using a bag of the mixed Thermit per pound of wax in the pattern, but if the amount of Thermit calculated comes to 10 bags or more, one of these bags can be dispensed with, i.e., instead of using 10 bags use 9 bags, and instead of 20 bags, use 18 bags, etc., as the greater amount of punch-

ings makes it unnecessary to use so much of the mixed Thermit.

Calculating Thermit in Advance

Where it is desired to calculate in advance the amount of Thermit required for a weld it is first necessary to estimate the number of cubic inches in the space to be filled with Thermit steel, i.e., the space between the ends of the sections to be welded together and the cubical contents of the Thermit steel collar or reinforcement fused around the weld. Allow ¾ of a pound of RAILROAD THERMIT to the cubic inch and this will be sufficient not only for the weld proper but will provide sufficient metal for pouring gate and riser. In estimating the cubical contents of the collar the simplest method is to multiply the width by the greatest thickness (i.e., the thickness at the middle part), then multiply this product by 0.7. This will give the average area of the cross-section of the collar. If this is then multiplied by the total length of the collar around the outside of the frame, and if all measurements are taken in inches, the result will be the number of cubic inches in the collar.

CRANKSHAFT AND SIMILAR REPAIRS

Aligning Sections

In all welds of crankshafts and other shafts, rudder stocks, crossheads, etc., the lighter part or section should be carefully supported on flat blocks so that it will be stable without any clamp and so that it can be moved backward and forward in the line of the weld without affecting the alignment. A strong clamp should then be set in place to hold the pieces in line while ramming the mold, but should be removed from the lighter piece before preheating and pouring. In repairing a break in a small section adjoining two heavy sections, it might even be advisable to support one or both of the heavy sections on rollers as their weight alone might very likely "pull holes" in the weld.

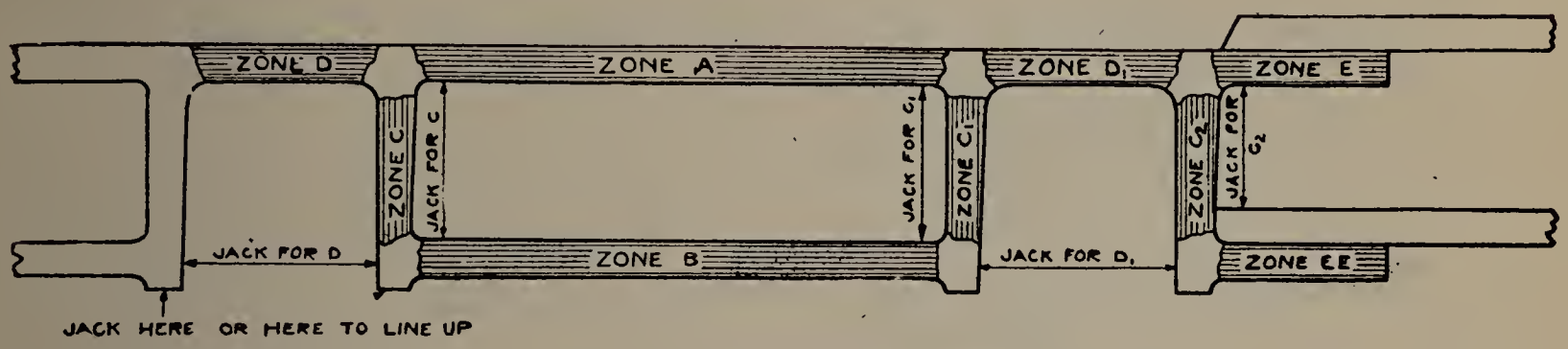
Special V-Blocks

In welding crank shafts it is customary and best to align the shafts on V blocks. These V blocks are heavy pieces accurately machined and slide in a machined slot of a heavy bed plate. The V blocks should be spaced along the slot of the bed plate so as to correspond with the journals of the crank shaft. Parallel to the main slot of the bed plate and on either side of it are smaller slots similar to those in planer beds. The heads of the holding-down bolts are placed in these slots opposite the V blocks and a short bar or channel placed across the shaft and clamped down by means of nuts on the holding-down bolts.

The V blocks should be so placed on the main journals that the shaft can slide at least ¼ in. either way parallel to its axis without a shoulder or crank throw striking any part of the V blocks. Experience has shown that crank shafts usually break in a main journal or in a pin journal close to a crank throw or slab, or, the break may occur in the slab itself. It is usually desirable to line up the shaft with the throws in a horizontal position. When the break is in the pin journal, however, the slabs should be in a vertical plane, with the defective pin journal lowermost, in order to avoid having a large amount of molding material between the slabs, which would prevent contraction of the weld in the pin journal.

Design for V Blocks

In the case of shafts with a break in one slab or throw close to the pin journal, the shaft is lined with the throws horizontal in special V-blocks, as shown in Fig. 6 which will allow a horizontal motion due to expansion and contraction after the mold is rammed. If then, the proper allowance for contraction is made the shaft should come back into line because the force tending to separate the fracture will not be resisted and will be subsequently offset by an equal contraction. On the other hand, such V



Fracture Location	Remarks
Zone A*	Heat zone B to get 3/16" to 5/16" expansion, according to size of frame and length of preheating time and hold about half an hour, or as previously instructed under caption, "Hold up Expansion." Preheater or basket fire.
" B*	Heat zone A to get 3/16" to 5/16" expansion according to size of frame and length of preheating time and hold about half an hour, or as previously instructed under caption, "Hold up Expansion." Preheater or basket fire.
" C, C1 or C2	Jack at C, C1 or C2, 3/16" to 5/16" according to size of frame and length of preheating time and hold about half an hour or as previously instructed under caption, "Hold up Expansion."
" D or D1	Jack at D or D2 3/16" to 5/16" according to size of frame and length of preheating time and hold about half an hour or as previously instructed under caption "Hold up Expansion."
" E	Cut out unfractured member of splice to clear collar.

*When heating either Zone A or Zone B, the adjacent pedestal brace or braces should be put in place before commencing to heat so as to distribute the expansion and not upset or distort the leg.

Fig. 10.—Method of Preventing Unequal Stresses When Welding Locomotive Frames Broken at Various Points.

blocks will permit of watching the contractions of the shaft so that different allowances can be made on the next shaft, if necessary.

These V blocks should be made in such a way that they will be divided in two parts horizontally. The upper and lower parts should each have divisions accurately marked

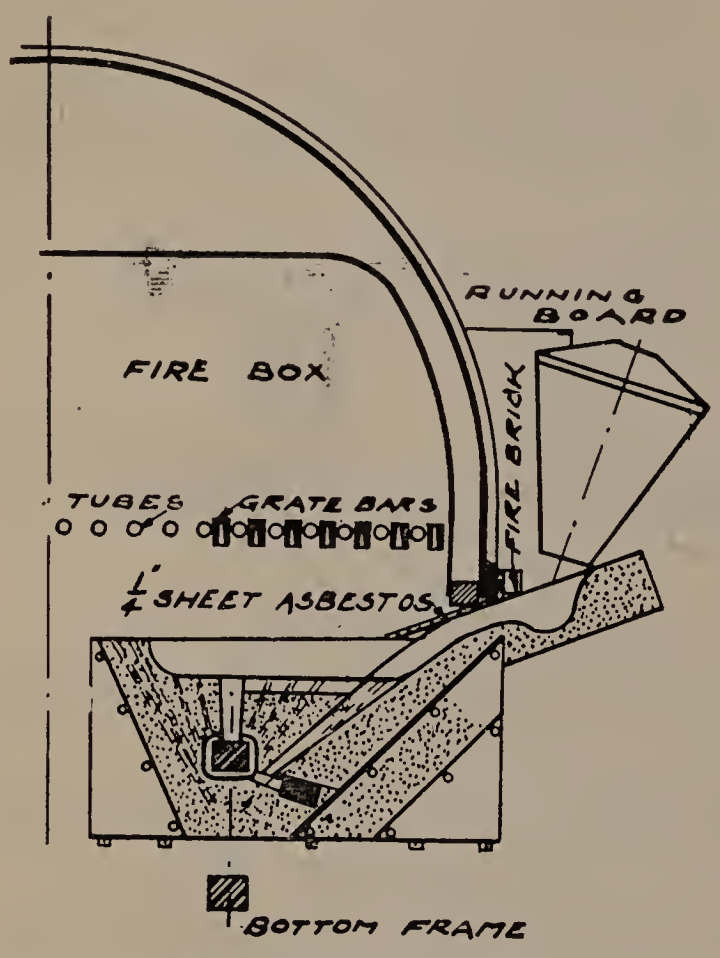


Fig. 11.—Method To Be Employed in Making Welds in Places Which Are Not Easily Accessible.
If Trough Is Lined with the Special Molding Material, This Should Be Thoroughly Dried Before Using. It Is Better to Line the Trough with Magnesia Tar.

on them next to the dividing line, the central division being longer and heavier than the rest. When the two parts of the V blocks are central on each other, accurately turned pins, preferably tapered, may be inserted in reamed holes passing through the two lugs so as to securely fasten them together. This locates accurately the central position where the shaft is to be lined up "in line." Where a horizontal contraction is to be allowed for, the pin should be left out of certain V blocks and the parts of these V blocks slightly shifted on each other if necessary. If the V blocks pins are not in place the holding-down bolts can be relied upon to hold the shaft in a desired position during the ramming of the mold. When the preheating is started these bolts should, of course, be removed and the shaft allowed to move freely. Another advantage of this type of V block is that flat shims can be placed between the halves of the V blocks to allow for different journal diameters instead of placing the shims on the slanting face of the V blocks. The thickness of the shims will, of course, be just half the difference in the diameters of the journals.

Expansion and Contraction

In allowing for contraction of a Thermit weld it must be remembered that the actual contraction of the small amount of Thermit steel in the space between the pieces is almost negligible, whereas the actual contraction of the weld may vary from 1/16 in. to ¼ in. This is due to the fact that during the preheating operation the ends of the pieces at the fracture expand or approach each other by the amount of the expansion of the adjacent parts by the preheating. For instance, if the fracture is opened up ¼ in. to allow for the contraction and the expansion of the parts during the preheating approach each other almost ¼ in. (perhaps 1/64 in. less) the parts should be almost exactly in line after welding. In welding large sections slightly greater allowances for contraction should be made than in smaller ones, because to bring the fracture to the proper heat takes a longer time and consequently the heat "soaks" further along the parts, causing a greater expansion and a greater tendency to close up the distance between the fractures.

CRUCIBLES

Construction of Crucible

The Thermit reaction in Thermit welding takes place in a magnesia tar lined crucible (Fig. 7), which has at the bottom a hard burnt magnesia stone (AA). This latter, again, has a tubular opening, into which a small magnesia stone or thimble (BB) of conical form is made to fit. This thimble provides a channel through which the liquid Thermit steel is poured. To replace, it can be easily removed by gently knocking up-

DETAILS OF AUTOMATIC CRUCIBLES, LINING MATERIALS, CONES, STONES AND THIMBLES

Size of Crucible	Capacity in Pounds of R. R. Thermit	Gross Shipping Weight of Crucibles, Pounds.	Outside Diameter at Top, Inches	Height, Inches	Size of Magnesia Stone for Relining	Size of Magnesia Thimble to be Used	Size of Plugging Material to be Used	Thickness of Magnesia Tar under Stones, Inches	Weight of Magnesia Tar Required for Relining Pounds	Size of Crucible Cone Corresponding to Size ofCrucible	Shipping Weight of Cones Pounds
No. 1	6	40	8½	8½	No. 1	No. 1	No. 1	⅜	8	No. 1	50
No. 2	8	60	9½	9	No. 1	No. 1	No. 1	⅜	20½	No. 2	50
No. 3	15	110	11½	13	No. 2	No. 2	No. 1	¾ to 1½	42	No. 3	50
No. 4	25	125	13½	15½	No. 2	No. 2	No. 1	½	61½	No. 4	125
No. 5	35	150	16½	16	No. 2	No. 2	No. 1	½	87	No. 5	150
No. 6	70	250	19	19½	No. 2	No. 2	No. 2	½	141	No. 6	225
No. 7	140	450	24	23½	Nos. 1 and 2	No. 2	No. 2	½	216	No. 7	375
No. 8	210	525	26½	27	Nos. 1 and 2	No. 2	No. 2	½	258	No. 8	375
No. 9	280	650	29	29	No. 3 and 3 Spec.	No. 3	No. 3	½	327	No. 9	600
No. 10	400	775	32½	32½	No. 3 and 3 Spec.	No. 3	No. 3	½	408	No. 10	600

ward and a new thimble inserted. It is safer to use a new thimble for each reaction.

The object of designing the crucible with an opening at the bottom is to permit the steel which is formed by the Thermit reaction and which settles to the bottom of the crucible being tapped into the mold without any danger of the slag which flows out afterward coming into contact with the parts to be welded.

Plugging the Crucible

The crucible is closed before charging by first inserting the thimble (BB) wrapped with one thickness of uncreased paper. This is plugged with plugging material as follows: The tapping pin (F) is suspended through the thimble and over this is placed the asbestos washers (E) and then the metal disc (D). Cover with refractory sand (C), using the entire contents of the package.

Plugging material, which includes the tapping pin, is supplied by the Metal & Thermit Corporation, ready for use.

The crucible is tapped by knocking the tapping pin upwards as previously described. After crucibles have been used several times they wear at the bottom and more care must be used in plugging to prevent premature tapping. Very often it is possible to patch worn crucibles with magnesia tar and thus prolong their life.

Crucible Lining

The crucible and the thimble through which the metal runs after the reaction are two of the important factors in the Thermit Process. The high temperature, together with the violent ebullition of the molten metal during the reaction, necessitates a lining which is not only mechanically strong, but of a very highly refractory substance. It has been found that Magnesite lined crucibles are the only ones which satisfy these conditions. This can be furnished in the form of Magnesia Tar, the tar acting as a binder for the magnesite and is burned out in the process of baking.

The following directions should be followed in relining crucibles, and where any number are to be relined in this way the Metal & Thermit Corporation will furnish drawings and specifications for a furnace required for baking the crucibles which has been found best for the purpose. The same company also furnishes the necessary cast iron cones and tamping tools.

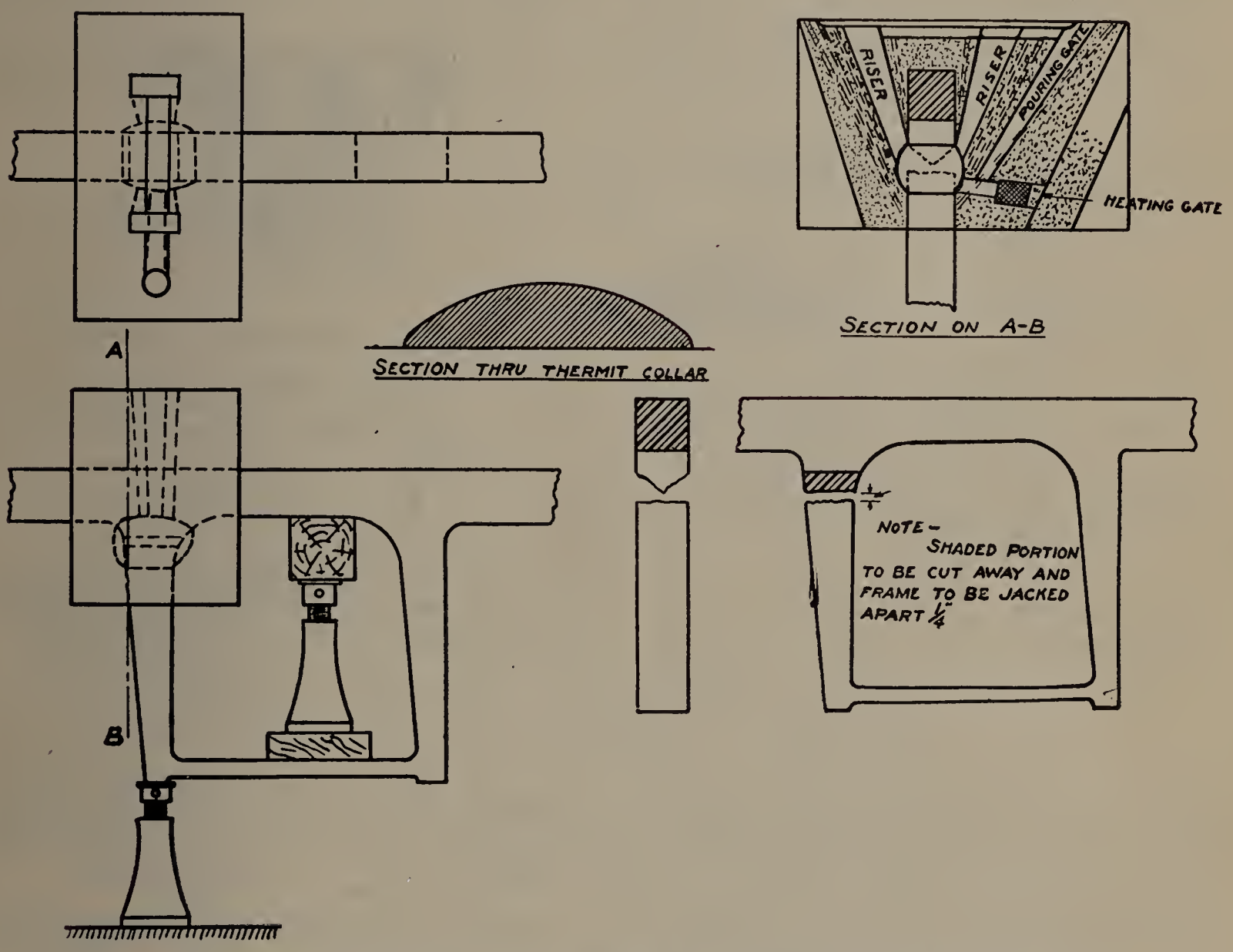


Fig. 12.—Method To Be Employed in Welding Locomotive Frame Broken in Leg.

The amount of Magnesia Tar required for each size of crucible will be found in the table on preceding page.

In order to protect and hold the mass together, a sheet iron shell, conical in shape, is provided having at its bottom an iron plate with a hole in it through which the liquid Thermit steel will pass.

The Magnesia Tar lining material should be heated until it becomes plastic. A few handfuls should then be placed in the bottom of the crucible shell and a Magnesia Stone, as shown in Fig. 7, imbedded in this material and centered over the hole (see table and Fig. 8, in regard to the sizes of stones required for different sizes of crucibles). More Magnesia Tar should then be rammed around the stone to hold it firmly in place. The cast-iron crucible cone should then be placed in position with the small projecting teat at the lower end set in the hole in the Magnesia Stone—the teat on the cone is the same dimensions as the thimble previously described. The upper part should then be centered inside of the shell

by means of wedges inserted at equal distances along the circumference.

The Magnesia Tar may then be rammed into the space between the cone and the shell, a little at a time and **tamped hard,** for upon the density or hardness of the lining depends the life of the crucible. Special iron tools should be made up for this tamping and should have flat ends. Good hard blows should be struck with a hammer on the upper end of the tool when ramming in the lining, or, better still, use a pneumatic bench rammer for this purpose.

Do not put in the material too rapidly, and let it be remembered that the better and more uniform the tamping, the longer the crucible will last.

Thimbles

The portion that has to withstand the most severe strain of all is the part at the bottom of the crucible, or walls of the hole through which the metal is tapped. It has to stand the wash and pressure of the weight of the moving liquid metal and slag under great heat.

The Magnesia Stone which is centered in the bottom of the crucible and around which the material for lining is packed, has a tapered hole in the center. The thimbles are of the same taper as the hole in the Magnesia Stone and are set into the latter. When the thimble is used up (either through enlargement of hole or by spitting) it can be knocked out and replaced with a new one, so

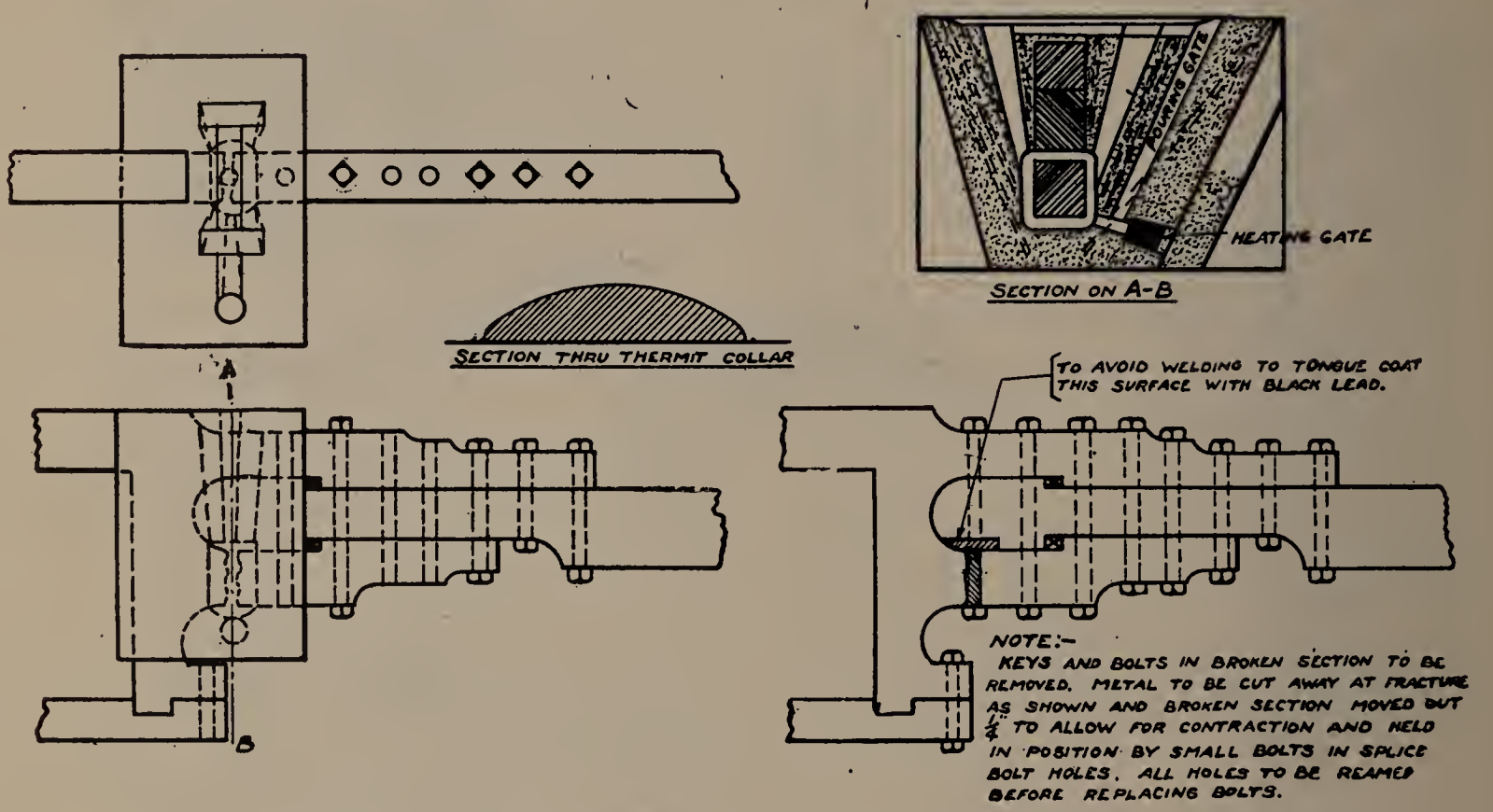


Fig. 13.—Showing Method To Be Employed in Welding Frames Broken in Splice.

As the mass nears the top, the wooden wedges should be removed as the lining already in place will hold the cone in position.

When completely filled and tamped, a mark should be made with a piece of chalk on the cone, and the point opposite to it on the lining, so that when the cone is withdrawn it may be replaced exactly as before. Then take the cone out, exercising care not to disturb the lining, place a layer of wrapping paper or newspaper over the tar lining, then replace the cone carefully, so that the marks previously made come opposite to each other. After this, put on the crucible ring and lute carefully around the top with fire clay to protect the upper part of the lining from the heat in baking. It is also well to place damp fire clay around the bottom of the crucible and inside of the stone for the same purpose.

The crucible is now ready for baking and for this purpose it should be placed in a suitable oven. The heat should gradually be raised until the cast-iron cone becomes red hot and should be held at that temperature until all the fumes stop coming off from the tar, after which it can be allowed to cool gradually before removing from the oven. If the crucible is baked too long the lining will appear crumbly and the life of the crucible will be very much shortened. Baking for too short a time will leave some of the tar in the lining and cause a violent Thermit reaction. When cool, the clay luting may be removed, the cone taken out and the crucible is ready for use.

that the full life of the crucible may be utilized. Thimbles should be wrapped with one layer of uncreased paper before being placed in position.

Care of Crucibles

Crucibles should be very carefully handled, as the lining is apt to crack or fall out under rough treatment. It is also always

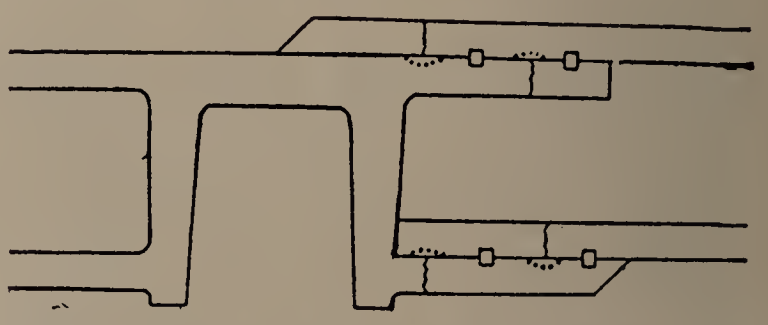


Fig. 14.—Showing Method for Drilling and Cutting Unbroken Member for Splice Weld.

important that they be stored in a dry place, as the lining, being porous, will absorb moisture, and a moist lining will result in a very violent Thermit reaction.

After a crucible has once been used, it is not necessary to clean it of the slag adhering to the inside, as this is a very refractory material itself and helps preserve the crucible if left on. At the bottom, however, in the vicinity of the stone and thimble, the

slag has to be removed so as to clear the opening of the thimble or permit of an old thimble being knocked out and a new thimble inserted.

Crucibles should be stored with all the other Thermit welding apparatus under lock and key in a perfectly dry place and the key should be in the possession of the man having charge of the Thermit welding.

Very often it is possible to increase the life of crucible linings by patching worn spots with magnesia tar. This is particularly the case where they wear away at the bottom, thus exposing part of the magnesia stone and making it difficult to prevent premature tapping. Care should be taken to patch the lining at the bottom with magnesia tar so as to cover the stone. This magnesia tar should be thoroughly baked before placing the crucible in use. In some cases fireclay has been used for patching crucibles, but this should be discontinued

The method of heating and pouring should be the same as given for locomotive frame welds, with the exception that in this case it is necessary to heat the unbroken spokes of the same segment so as to open the gap as measured by the tram marks $\frac{3}{16}$ in. to $\frac{1}{4}$ in., and thus prevent shrinkage strains. This heat usually should be maintained for some time after the pour is made, especially if the loss of heat from spokes so heated is likely to be rapid.

It is advisable to insert a clamp between segments of rim to hold them in alignment during welding.

It is sometimes possible, where a section of spoke is broken out completely, to cast in a piece of Thermit Steel to replace that broken out. This should not be done, however, where the section is over 6 inches in length, owing to the increased strains which would be caused by the contraction of a piece of metal of that length. It would be

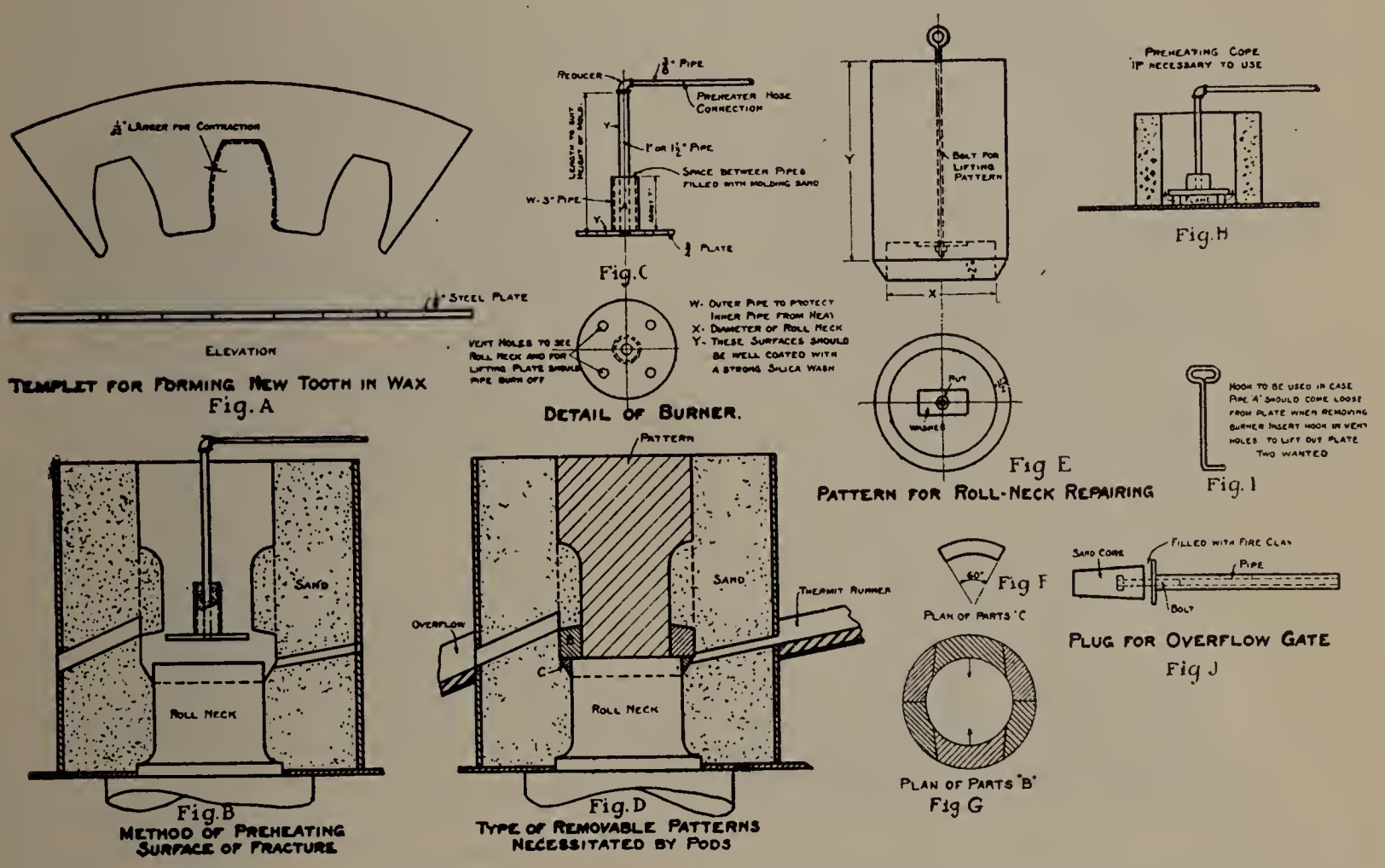


Fig. 15.—Showing Designs for Patterns and Heating Apparatus for Repairing Steel Pinions.

and magnesia tar should be used instead, as it stands up much better under the heat of the Thermit reaction. In addition to this, the clay, consisting principally of silica, will be reduced by the intense heat and reducing action of the aluminum introducing silicon into the steel. This together with the many impurities in the clay itself, may have a bad effect on the steel.

LOCOMOTIVE REPAIRS

Driving Wheel Repairs

In making repairs on spokes of locomotive drivers, follow essentially the same method of procedure as given for repairing locomotive frames by the wax pattern method.

It is first necessary, of course, to remove the tire, after which clean the fracture and cut away the metal in accordance with previous directions. Then construct a pattern of yellow wax as described for frame welding. This pattern may usually be made not over 3 inches wide and ½ inch to ¾ inch thick at the middle part, the cross section, showing approximately, the segment of a circle.

better in such a case to insert a section of steel of the proper length and weld it at each end of the parts remaining of the original spoke, allowing one weld to cool before making the other one.

In cases where a wheel is cast solid instead of in segments, the rim must be cut through, so as to make a segment which will include the broken spokes. When replacing tires, keys should be fitted in the usual way.

FRAME WELDING

Preparing Frame for Weld

After having removed such parts of the engine as to make the fracture accessible and allowing room for the mold box 15 inches wide, set screw jacks to support the frame so that neither section can sag. Then place tram marks on the frame so as to gauge the allowance to be made for contraction. Then cut out the metal along the line of fracture and clean frame according to the previously mentioned general instructions for Thermit welding.

Next, clean the frame thoroughly for a space of at least two inches so as to expose good bright metal on each side of the frac-

ture and be sure to remove all dirt and grease as far back as the mold box will reach, so that when the mold is rammed up and the heat applied there will be no grease to burn out and leave a space between the mold and the frame. **If oxy-acetylene is used for cutting, be sure to remove all oxide and scale left on the frame from the cutting operation.**

Make sure that the frame is in perfect alignment, after which expand frame according to the location of the break and section. If the fracture occurs between jaws, set in a screw jack and force the frame apart $\frac{3}{16}$ in. to $\frac{5}{16}$ in., depending upon the size of the frame and the length of time of preheating. This allowance is closely dependent upon the length of time of preheating because, the longer the time, the more the heat soaks back into the frame and the more the original gap allowed will be reduced. In other words, the longer the preheat, the greater the allowance for contraction. A little careful observation on the first few welds made will soon make the operator expert in judging this allowance. If the expansion cannot be taken care of with a jack or other mechanical means, it will be necessary to heat a parallel member by means of the flaming burner attachment on the double burner preheater or by a basket fire. If possible, heat considerably more of the parallel member than is included in the mold box of the member being welded, in order to gain sufficient expansion by this method. Do this while the fracture is being preheated, but take care not to heat too hot, as the frame is liable to upset. A black heat is usually sufficient, but where there is insufficient length in the parallel member, it can be heated red, if necessary, and if the operator takes sufficient care to see that he does not reach the danger point at which the frame might tend to upset.

For application of wax pattern, mold riser, wooden patterns, expansion by heating, quantity of Thermit required, see general directions for Thermit welding.

WELDING LOCOMOTIVE FRAMES BROKEN IN THE SPLICE

Cut Into Unbroken Member

In cases where locomotive frames break in the splice, the best and most satisfactory method of making the repair is not only to weld the broken sections together, but to cut out a piece about 1 inch by 5 inches of the unbroken member so that Thermit steel can flow entirely around the fractured part. (See Figs. 13 and 14.)

Weld Upper and Lower Members Together

As frames always break through bolt holes, due to the weakening of the frame by the holes, it is reasonable to suppose that the frame is not strong enough at those particular points. By cutting out as suggested above so as to run the Thermit steel entirely around the broken sections, and at the same time weld up the bolt hole, it will be found that sufficient Thermit steel is concentrated between the two frame members to thoroughly fuse with the unbroken member and weld it to the broken member.

The unbroken sections of frame should be cut out either by means of the oxy-acetylene torch or by drilling a line of holes as shown in Fig. 14, and then cutting out the metal between the holes. Of course, the broken frame at the fracture should also be cut out to provide a gap before making the weld as shown in the table of welding portions.

Strong Job Assured

By making the repair in this manner, a good strong job is assured, and if the bolt hole is welded up and the two members welded together, future breakage at these particular points is practically eliminated.

Easy to Separate

The only objection which can be raised against this practice is the trouble of separating the members in case the splice is to be removed or in order to take out or renew a cylinder. This objection, however, is not serious because it is only necessary

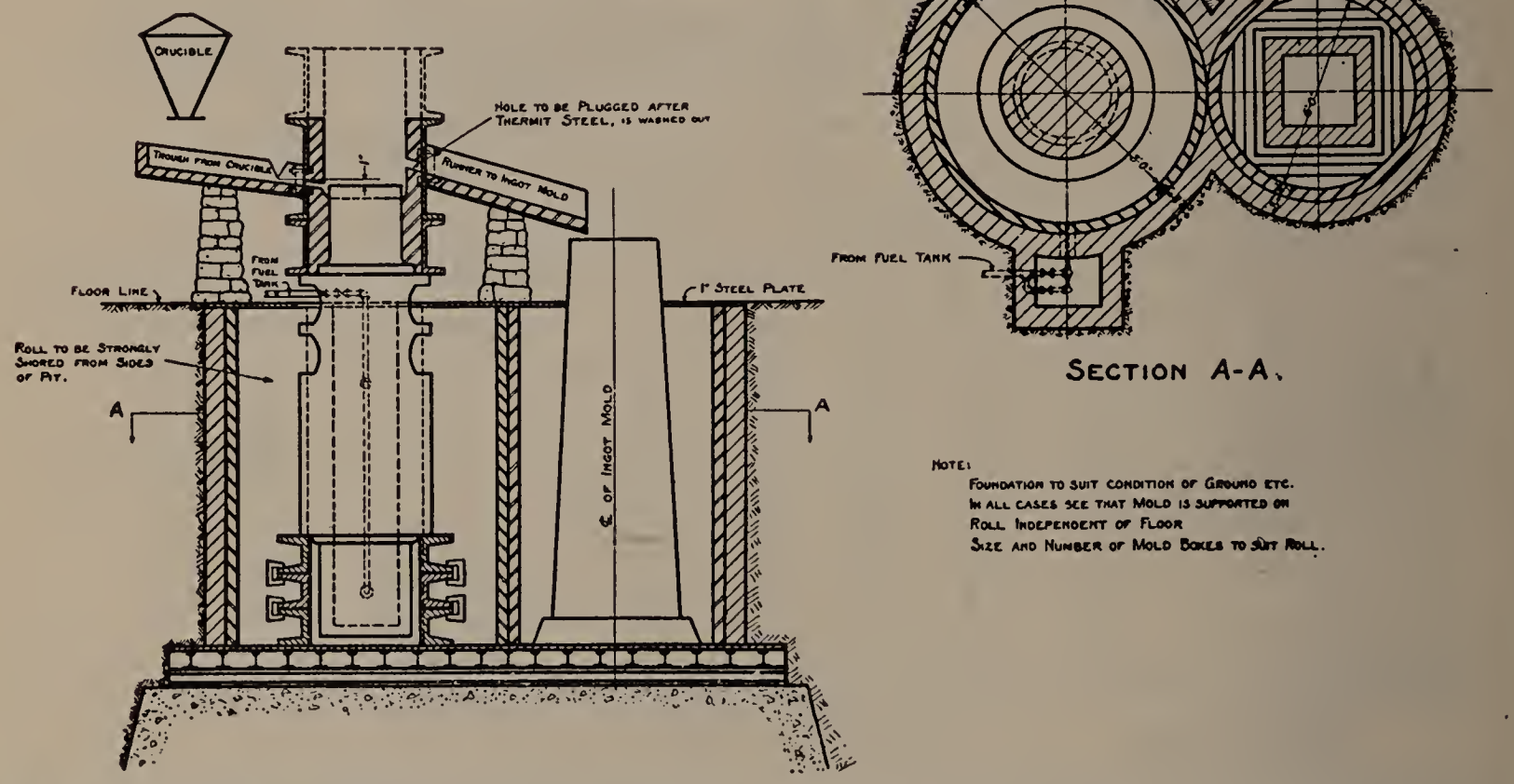


Fig. 16.—Showing a Design For a Permanent Pit for Welding Necks on Large Rolls and Pinions. If Desired, a Removable Fire Brick Partition May Be Used Between Roll or Pinion Pit and the Ingot Mold Pit.

to drill a line of small holes where the parts are welded together and the member can then be removed. When replacing, it is best to cut a key-way where the frame is cut out and then bolt together in the same way as when the frames were originally assembled.

Pinion Repairs

Frequent breakages of heavy pinions in steel plants have resulted in the development of a very ingenious adaption of the Thermit Process for their repair. Obviously the casting on of a new neck entirely out of Thermit steel would be a very expensive operation and it would also be costly and difficult to turn up a new piece of steel and weld it on to the original section, as the weld would be a very large one to make.

if the process is to be used for the first time for such repairs, arrangements be made with the Metal & Thermit Corporation to furnish an experienced engineer to supervise the first welds and give personal instructions for executing this class of work. The printed instructions published herewith have been written more especially for the purpose of acting as a guide for reference and while it is hoped that these are sufficiently adequate and complete to enable anybody to make these welds, the personal supervision and instructions of an experienced engineer are much to be preferred.

Two Methods

Two methods are given for executing these repairs. The first method which follows is

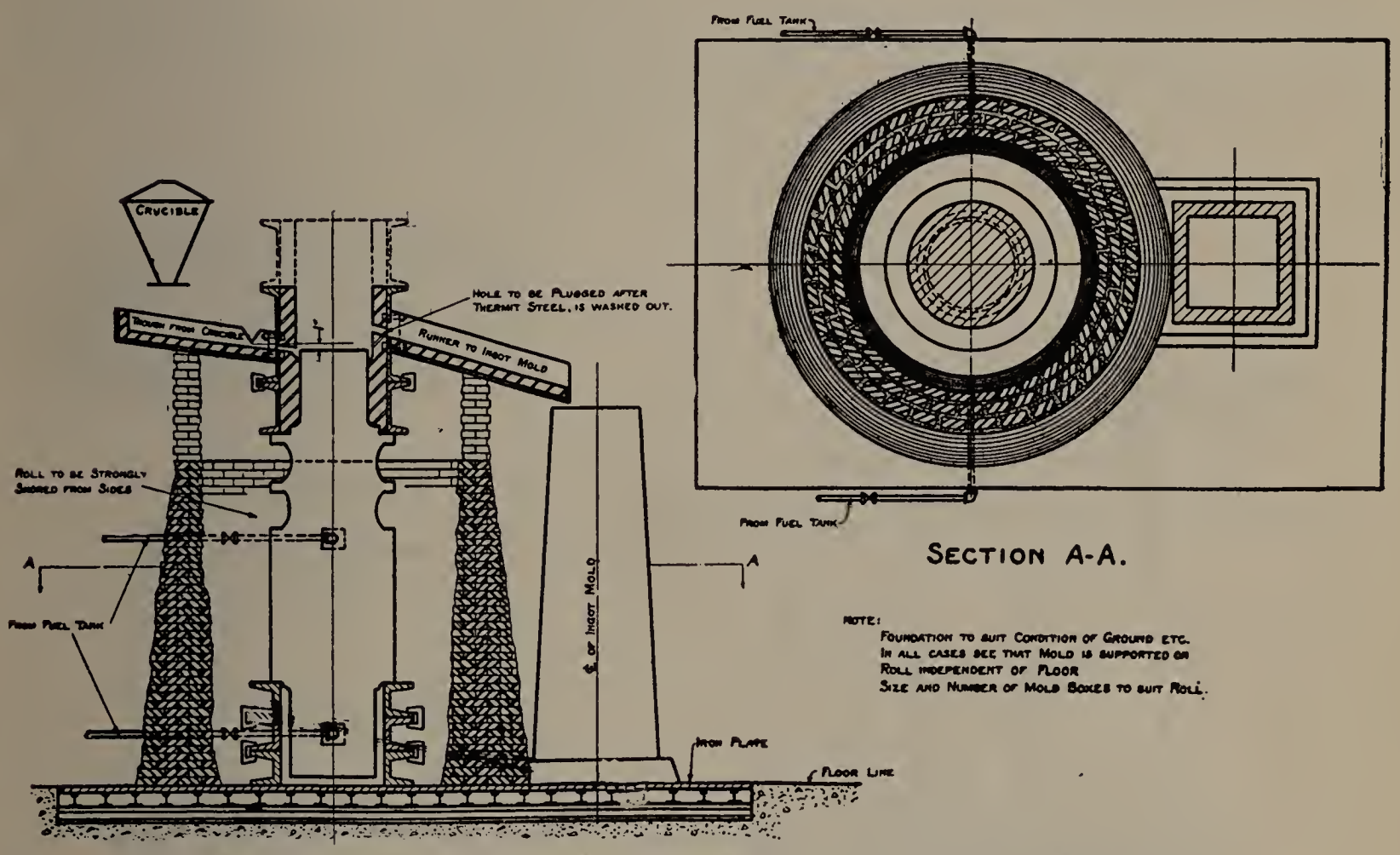


Fig. 17.—Showing a Method for Welding Roll Necks Without Digging a Pit.

Thermit Used for Heating

Experience has shown, however, that the intense heat of the Thermit reaction can be utilized for the purpose of bringing the broken surface of the pinion to a fusing temperature, at which time a supply of liquid steel can be poured in from the ladle and this will unite with the original body of the pinion to form a new neck thoroughly amalgamated with the rest of the piece.

General Description

Briefly, the operation consists in constructing a mold around the broken section so as to permit of casting on a new neck to replace the one broken off. The original section is then preheated to red heat by means of gasoline or oil burners, after which Thermit steel from a crucible is allowed to flow over the fractured surface to a depth of 1 in. This completes the heating operation and brings the surface of the roll to the melting point. A supply of liquid steel from a ladle is then tapped into the mold and about 5,000 lbs allowed to wash through and overflow into an ingot mold so as not to be wasted. The overflow gate may then be closed and the mold filled to the top with steel.

Personal Instructions Best

Detailed instructions for these various operations follow, but it is recommended that undoubtedly the safest and surest method to use, but it involves considerably more trouble and expense than the second method. The first method is strongly recommended, however, and it is believed that it would be to the interests of steel plants having much of this work to do to equip themselves properly to follow out this method.

FIRST METHOD

Preparation of Pinions for Repairs:

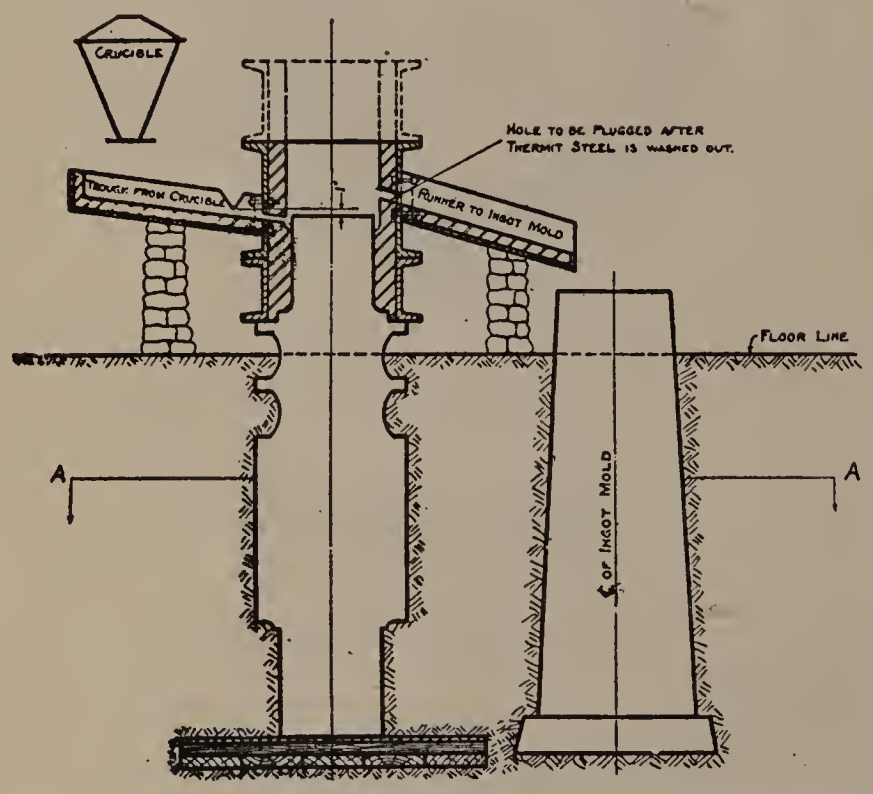
Before undertaking a repair of this kind the broken end should be cut off square so as to form a level surface when the roll stands in a vertical position. The object of this is to permit of a uniform covering of Thermit steel over the entire surface to be welded. If the break is in the pods, cut off two inches below the point where the pod joins the neck. If, when the neek is cut off, it should be found to contain any pipes or cavities, these should be bored out and steel plugs turned to a driving fit and driven into the cavities at least 5 in., care being taken that the plugs are driven in even with the surface on the end of the neck.

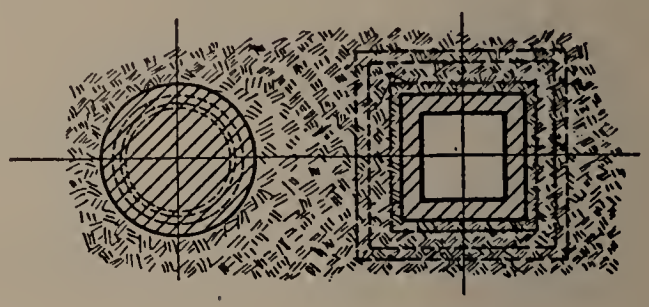
Another and better method is to dry out the inside of the cavity by heating and then fill with liquid steel. This will eliminate any danger of the Thermit metal melting

the plug and running into the cavity, which might cause a violent and dangerous eruption of the steel. Clean off all dirt and grease at least 20 inches from point of weld. A riser pattern should be provided undercut as shown in Fig. 15-E also a pouring gate and overflow gate pattern.

The riser pattern should be 3 in. larger than the pinion neck in diameter, and at the lower part, where it joins the neck, it should taper as shown. Where the operation requires the casting of pods, a special pattern should be made having the shape of the pinion neck with these pods. This pattern like the riser pattern mentioned above should be larger in diameter than the pinion neck and should taper at the bottom. The pattern should, if necessary, be made in sections so as to allow of being withdrawn from the mold.

Heavy circular cast steel mold flasks should be provided, the same as are used in steel foundry practice. In the absence of these flasks suitable ones can be made of ¼ in. steel plate. The bottom flask should





SECTION A-A.

NOTE:
FOUNDATION TO SUIT CONDITION OF GROUND ETC.
IN ALL CASES SEE THAT MOLD IS SUPPORTED ON ROLL INDEPENDENT OF FLOOR.
SIZE AND NUMBER OF MOLD BOXES TO SUIT ROLL.

Fig. 18.—Showing Method of Supporting Roll or Pinion to Be Repaired by Alternate Method.

be divided and bolted together so that it can be removed without trouble, as it is much easier to tear down the mold after this flask is removed than before.

In undertaking these repairs, it is recommended that a special pit be constructed as shown in Fig. 16. It is of the utmost importance when constructing the pit to provide a good foundation for the bottom of the pit. It has been found in many cases that steel plants are built on low and marshy ground, therefore when a pit is dug, the ground is apt to be soft and many times water seeps in. Unless precautions are taken to provide a good foundation, heavy pinions are apt to settle before the welding operation is completed. This is liable to cause a loss of the repair and sometimes a serious explosion might result caused by the hot metal coming in contact with moisture. When an adequate foundation has been provided, set the pinion and the ingot mold in place and brace them strongly to the sides of the pit.

Arrange the heating burners which may use gas, gasoline or kerosene. This arrangement is shown in Fig. 15, although the complete connection to the fuel supply is not shown.

Construct the mold as shown in Fig. 15 of sharp silica sand and fire clay. The usual proportions of the mixture are three parts of sand to one of clay, but this varies according to the sand and clay used. Coat the mold with a good steel wash and drive in nails or chaplets to hold the sand in position.

Attach the runners at the proper points and ram them with the same material, being careful to arrange the runner for the Thermit exactly as shown, i.e., the runner gate is so placed that when the Thermit steel has run into the mold the top surface of the neck wil be covered with superheated Thermit steel to a depth of about 1 in., and the slag from the Thermit reaction will flow from the crucible and run out of the V-shaped notch in the side of the runner, thereby preventing any slag from entering the mold.

The overflow runner should have sufficient pitch so that the liquid steel will flow to the ingot mold readily without spattering. Fire bricks should be laid on top of the ingot mold in order to prevent steel from spattering at that point.

When the mold is completed start the preheating of the body of the pinion. If gasoline or kerosene is used, three double or five single Thermit preheaters will be required and another one should be kept filled and ready to be cut in when any one of the others has become empty. This will prevent loss of heat while a preheater tank is being refilled.

As the body of the pinion approaches a red heat start the preheating of the top of the neck as shown in Fig. 15-B. Heat this surface to a good red heat, timing the operation so as to have both neck and body of pinion red hot at the time the open hearth steel is tapped out of the furance.

While the preheating of the neck is progressing set the automatic crucible, size No. 7, as shown in Fig. 17 charging it in accordance with the directions given previously, so that it will be ready when needed.

In calculating the amount of Thermit required for this type of repair, allow one pound of plain Thermit for each square inch of surface it is desired to melt down.

Be sure that the cope has been baked while preheating of neck is going on (either in an oven or as shown in Fig. 15-H) and is located conveniently so that it can be brought up with the crane at the proper time. After the furnace is tapped raise the ladle of steel and try the stopper by makirg

a couple of pours, to be sure that the stopper works properly and will shut off tight.

Move the ladle to a point near the mold so that no time may be lost between pouring the Thermit steel and washing through the steel from the ladle. REMOVE THE PREHEATERS TO A SAFE DISTANCE.

Ignite the charge of Thermit in the crucible and when the reaction is over (usually 35 to 50 seconds) tap the Thermit steel into the mold. When all the steel from the crucible has flowed into the mold the slag will commence to run over the V-shaped notch in the pouring runner. Move the crucible out of the way and plug the pouring gate with a sand core provided for this purpose, banking up securely behind it to prevent leakage.

Lower the ladle of open hearth steel to a point close to the top of the mold and tap the steel into the mold, running through about 5,000 lbs. into the ingot mold which has been set for the purpose as shown in Fig. 16.

Plug the runner gate with a core constructed as shown in Fig. 16-J, and bank up well behind it so that there will be no danger of a runout. **Be careful in plugging this gate on account of its size.** After the plugging is completed and banked up, the sand should be weighted down as an extra precaution to prevent accident.

After the overflow has been securely plugged fill up the mold with steel from the ladle and cover it well with dry sand or charcoal to keep the metal hot.

If a cope is used, clean off the surface of the top of the mold and set on the cope. clamping it securely, and then fill the cope to the height desired with steel and again cover over with dry sand or powdered charcoal.

If the body of the roll or pinion has cooled to any etxent it would be desirable to again preheat it. After the body of the pinion is sufficiently preheated cover the pit to make it as nearly air tight as possible, so as to cause the roll or pinion to cool slowly. By doing this further annealing is unnecessary.

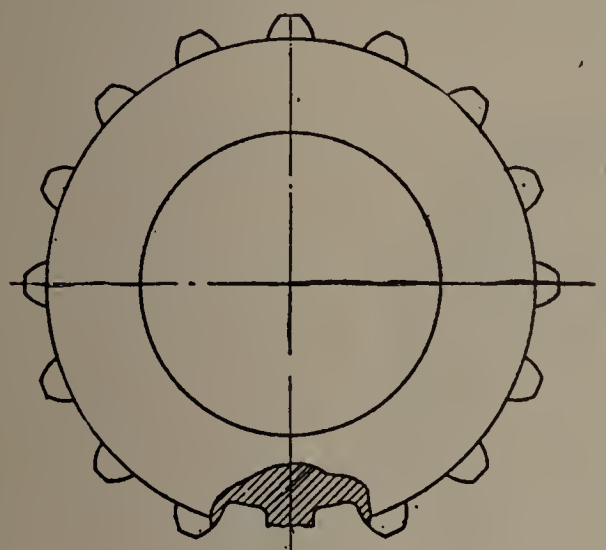


FIG. 1

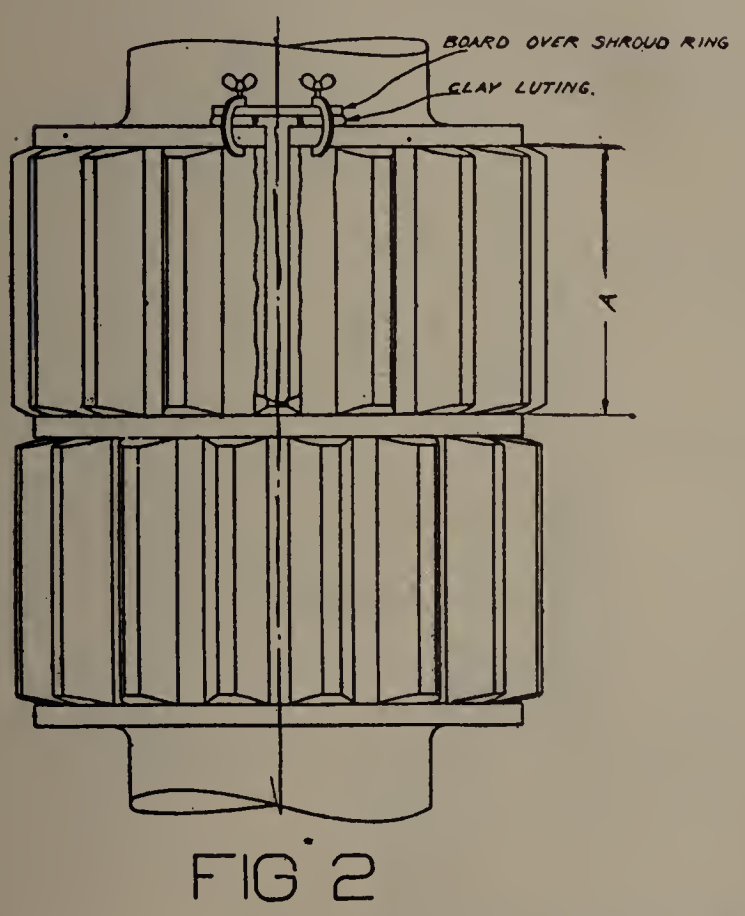


FIG 2

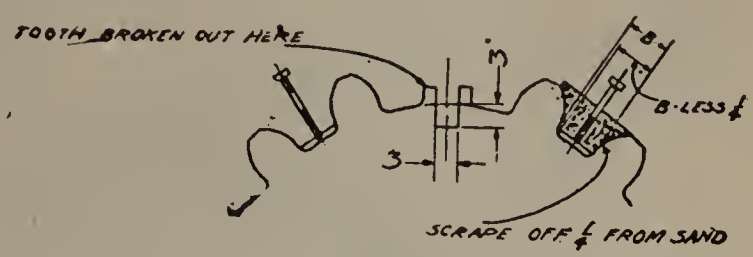


FIG. 3

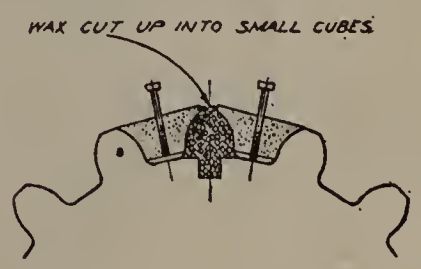


FIG. 4

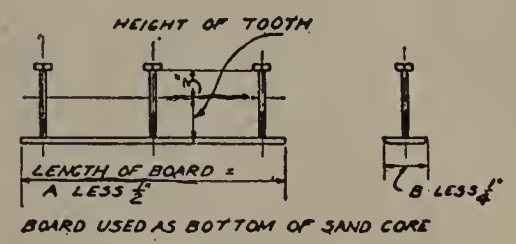


FIG. 5

FIG. 6

Fig. 19.—Preliminary Steps in Welding Teeth in Pinions.

Fig. 1.—Section Through Broken Teeth, Showing Usual Line of Fracture.
Fig. 2.—Showing Method of Cutting Shroud and Attaching Board and Clay Luting for Welding Shroud.
Fig. 3.—Sand Core Rammed to Form Mold for One Half of Tooth.
Fig. 4.—Both Cores in Position and Filled with Wax.
Fig. 5.—Design for Board to Support Bottom of Sand Cores.
Fig. 6.—Section and Elevation of Sand Cores Used As One Half of Wax Pattern Mold.

After the pinion is sufficiently cool (usually about 48 hours or more) remove from the mold and machine to size.

In some steel plants it is considered preferable not to use a cope but to build the mold all in one piece to the height of the new neck. This method simplifies the making of the mold and the pouring of the weld, but sometimes complicates the operation for the following reasons:

When riser patterns are withdrawn it is a little more difficult to remove loose sand from the mold.

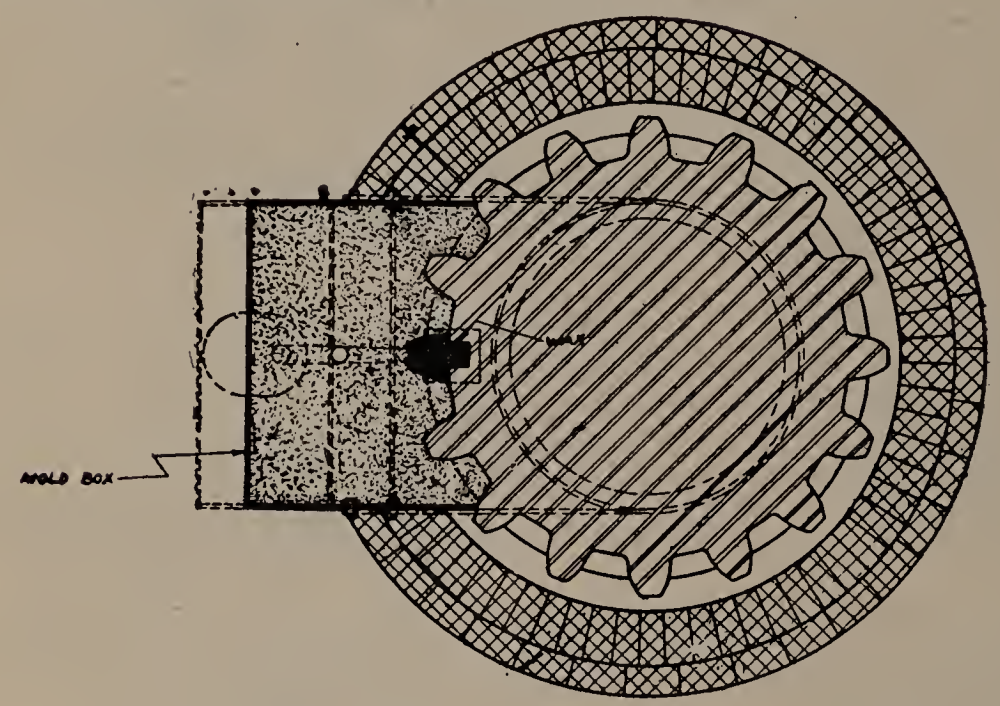
In preheating it is not so easy for the operator to see what he is doing.

There are times when these necks will be as much as 5 feet high, which makes it a little unhandy to work around the mold.

There are numerous arguments on both sides of the question, but either method will give good results. For short necks, however, a cope can probably be dispensed with without introducing any difficulty.

ALTERNATE METHOD

While the preceding directions cover the welding of pinions under what might be considered ideal conditions, it is not always possible to do the work in this way, and where such is the case it is recommended that the following directions be followed as they represent a simpler method, yet one which has always resulted in satisfactory repairs.



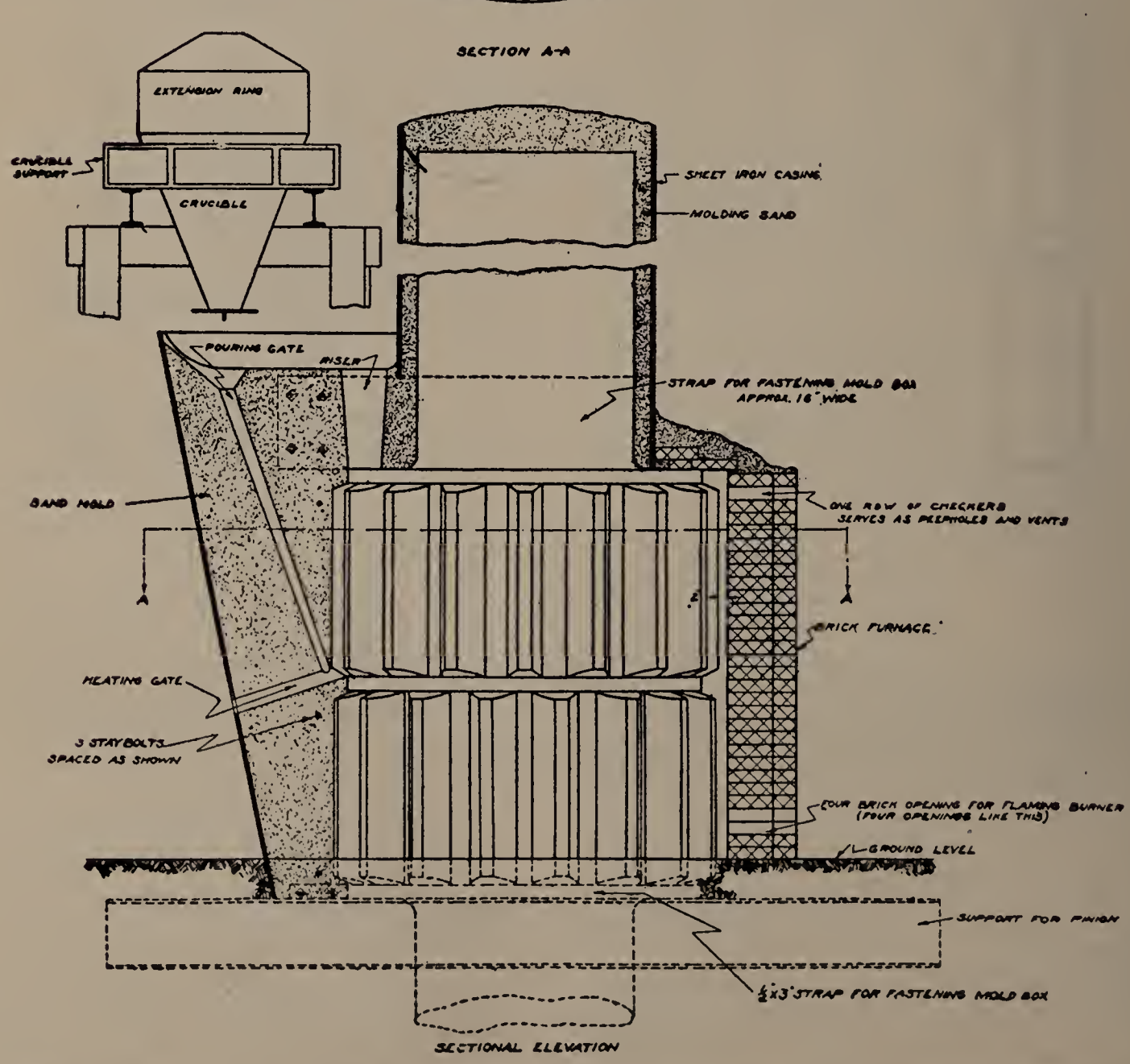


Fig. 20.—Method of Setting Up Mold Box and Brick Furnace in Pinion Tooth Welding.

Patterns, mold box, runners, etc., should be constructed in accordance with directions given for the previous method.

In undertaking these repairs great care should be exercised in supporting the pinion so that there is no danger of its settling under the added weight of the mold and the steel which is poured into it. If it is not desired to go to the expense of constructing a special pit as outlined in the previous method, a satisfactory and economical method is to dig a hole in the ground about 8 ft. diameter and of sufficient depth to receive at least ¾ of the entire length of the pinion. Cover the bottom of the hole by laying a double flooring of 2 in. planking, being careful that the planks in one layer run in opposite directions to those of the other layer.

On top of this place a steel plate in order to distribute the weight of the pinion over the entire floor area. Such a foundation has always proved adequate and is not expensive.

Set the pinion in the hole so that the surface to be welded is level and fill in all around the pinion with dirt, ramming hard to hold the pinion permanently in position.

Dig a second hole alongside of the buried pinion to receive the ingot mold. This should be at such a distance from the pinion that a suitable runner for the overflow steel can easily be placed. The top of the ingot mold should, of course, be lower than the top of the roll or pinion neck.

If the neck is broken off close to the body of the pinion, it is absolutely necessary to provide arrangements for preheating the body protruding above the ground in order to avoid shrinkage strains. A simple way to do this is to build up a brick furnace and heat in accordance with previous directions. More of the pinion body should protrude above the ground than shown in Fig. 18. If, however, there is one foot or more of neck protruding from the body of the pinion, it is not absolutely necessary to preheat the rest of the pinion.

The mold box should be constructed with heavy steel flasks or a substitute made of at least ¼ in. plate and should be supported entirely on the roll and independent of the ground.

With the mold box adjusted in place, ram up with good molding material in accordance with the previous directions, and then draw out the various wooden patterns. Nails or chaplets should be driven into the sand so as to hold it firmly in place. It is advisable to coat the mold with a good steel wash. When the mold is completed the preheating of the body of the pinion should be started. If this heating is not necessary, start preheating on top of the neck as shown in Fig. 15-B. If the body of the pinion is heated the heating of the neck should not be started until the pinion approaches a red heat.

Heat the surface on top of the neck to a good red heat, timing the operation so that it will be red hot at the time the open hearth steel is tapped out of the furnace.

While the preheating of the neck is progressing set an automatic crucible, size No. 7, as shown in Fig. 18, and charge it in accordance with previous directions, so that it will be ready when needed. If possible, it is best to support the crucible with a crane so that it can be quickly removed after it has been tapped.

In calculating the amount of Thermit required for a repair of this kind, allow 1 lb. of plain Thermit for each square inch of surface it is desired to melt down.

When the end of the roll neck is at a bright red heat bring the ladle of open hearth steel over the mold, or to a point near by, so that no time may be lost between pouring the Thermit steel and washing through the steel from the ladle. Try the stopper of the ladle to be sure that it works properly. REMOVE THE PREHEATING BURNERS TO A SAFE DISTANCE. Ignite the charge of Thermit in the crucible and when the reaction is over, usually 35 to 50 seconds, tap the Thermit steel into the mold. When all the steel from the crucible has flowed into the mold the

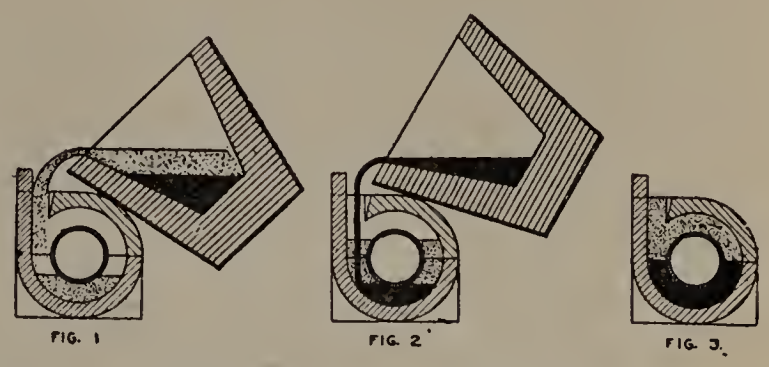


Fig. 21.—Thermit Pipe Welding Operation.
Fig. 1.—Slag Flowing Into Mold and Coating Outside of Pipe and Inside of Mold.
Fig. 2.—Slag in Mold and Steel Following, Displacing Slag in Bottom Part.
Fig. 3.—Both Slag and Steel in Mold But Steel Separated from Pipe and Mold by Film of Slag.

slag will commence to overflow from the pouring runner. Move the crucible out of the way and plug the pouring gate with a sand core provided for this purpose, banking up securely behind to prevent leakage. Then bring up the ladle of steel and top directly into the top of the mold over the roll neck. Run about 5,000 lbs. of steel over the neck and through the overflow runner into the ingot mold. Then shut off the ladle, plug the overflow gate with a core constructed as shown in Fig. 15-J. Bank up well behind it so that there will be no danger of a runout. Be careful in plugging this gate on account of its size. After the plugging is completed and banked up, the sand should be weighted down as an extra precaution to prevent accident. After the overflow has been securely plugged, fill up the mold with steel from the ladle and cover it with dry sand or powdered charcoal and allow it to cool slowly.

After cooling strip the mold and turn to proper size.

It is sometimes desirable where the body of the pinion has been preheated to continue this heating after the weld is completed. This can easily be done by again igniting the burners directed into the brick furnace. After the body is sufficiently preheated, remove the burners and fill in between the bricks and the pinion with dry sand so as to cause slow cooling. By doing this further annealing is unnecessary.

As mentioned in the description of the previous method, a cope may or may not be desirable, and this is left to the judgment of the operator.

Welding wobblers on roll and pinion necks can be done very successfully by adding 3% of pure manganese to the Thermit. This will give a hard wearing surface. The wobblers should be heated to about 1400 deg. Fahr. before welding, otherwise no amalgamation of the two metals will be obtained.

Pinion Teeth

These repairs usually consist of replacing teeth or parts of teeth which have broken out. They are peculiar in that the tooth is a comparatively small projection on an extremely heavy steel casting. For this reason, if the repair were attempted by the ordinary method, i.e., if the casting were preheated at the weld only as covered in the general instruction for making Thermit welds, the heat would be carried away into the casting so quickly, especially dur-

ing the interval of removing the preheating burner and tapping the crucible, that in most cases a poor weld would result. Furthermore, there would be great danger of cracking the pinion. Everything possible must, therefore, be done to conserve the heat at the weld and we find to do this efficiently, it is necessary that the whole pinion should be heated to a red heat. This may be done by bricking in the heaviest part and preheating it by means of oil or gas burners conveniently placed while the part to be welded is being preheated in the regular way. Thermit flaming burner preheater attachments are admirably adapted to this preheating work, as they give an extremely hot flame which may be adjusted to suit the conditions. Care should be taken, however, to bring up the heat slowly as otherwise there is danger of cracking the pinion.

In making all welds where a relatively small amount of Thermit steel is to be added to a heavy steel casting or where one, or both, of the parts to be joined is considerably heavier and larger than the Thermit steel part, it is necessary to take special precautions to secure thorough amalgamation of the Thermit steel with the heavier part, especially at the extreme edges of the line of junction where in service the greatest strain will come. The slightest imperfection at this line of junction or extreme fiber will cause a tear to start in service which will cause a fracture of the welded part. A perfect weld on this extreme fiber is made more difficult by the fact that the metal in the weld always shrinks a little more than the white hot steel of the pinion due to the slight difference in shrinkage between molten steel and white hot steel. It is necessary, therefore, that the fusion be obtained for a considerable depth even at the extreme edge of the Thermit steel. Fusion at this point is more difficult because the heat of the Thermit steel comes from one side only and not from all sides as it does near the center of the weld.

Increasing Surface of Weld

For all the above reasons it is desirable to increase as far as possible the surface exposed to the Thermit steel in the width of the weld. This at the same time produces edges or corners which melt more readily and thus aid in the fusion. These edges may be readily produced by cutting out a groove or slot in the main body of the pinion at the center part of the root of the tooth broken out. This slot should be half the width of the tooth in depth and also in width, i.e., if the tooth to be welded in is 6 in. wide at its root, the slot should be made 3 in. wide by 3 in. deep. The most economical way to cut this slot is to place the pinion on a planer and machine it out.

Cutting Slot

The cutting of such a slot also serves to bring the line of junction between the Thermit steel and the metal of the pinion well into the body of the pinion so that a strong and efficient weld is assured.

After the slot has been cut, the pinion in the vicinity of the weld should be carefully cleaned and then mounted vertically for the welding operation. In this mounting great care should be taken that the pinion is properly supported so that there will be no danger of its settling under the added weight of the mold box. This can be accomplished in the following manner:

Supporting Pinion

First dig a hole in the ground the proper size to receive the neck of the pinion. Then lay two tee rails across the top of the hole so that they will come underneath the shoulder of the pinion. If the ground is not sufficiently hard to properly support the tee rails, steel plates can be placed underneath in order to prevent the rails from settling into the ground.

Applying Wax Pattern

With the pinion properly supported in this manner the next step is to provide the wax pattern for the new tooth. The proper shaping of the wax pattern for welding teeth in pinions is one of the most important operations in the whole repair, if not the most important. The new tooth must mesh properly or the entire repair will have been made in vain. This meshing is dependent on the wax pattern, its proper placement and form.

Until about 1916 the usual procedure was to construct a rough wooden box a little larger than the tooth to be welded in and place this against the pinion where the new tooth is to be added, luting around the edges with fireclay. This box was then completely filled with molten wax, and when the wax had set the box was removed and the wax pattern brought to proper form by means of a template, as shown in Fig. 15-A. This template was usually made from ⅛ in. steel plate and the outline of three teeth cut into it by using three good teeth in the pinion as a guide. The center tooth, however, which represents the guide for the tooth to be welded in is cut 1/32 in. larger all around so as to allow for the contraction of the Thermit steel tooth.

The two outside teeth of the template can then be engaged with the teeth on each side of the wax pattern, and when the template is moved up and down it will cut the wax to proper shape and assure that the new tooth will be welded on in proper pitch.

This method has proved very satisfactory in practice, but is open to the objection that if the teeth of the pinion are worn irregularly the use of the template does not entirely take care of all these irregularities so that the new tooth will be of exact shape of the worn teeth.

Method to Be Followed:

It was to improve this condition and at the same time devise a method which would save considerable time in the making of these repairs that a new method was developed, which, briefly, consists in making a sand mold for casting the wax pattern, using the adjacent good teeth in the pinion as models to go by. A great many repairs of this character have been made and the method described has been thoroughly tested and found satisfactory in every way.

Mixing Sand for Cores

The pattern shown in Fig. 19-3 should be made and fitted as indicated, after which sand should be properly mixed for cores, using two parts of building sand to one of fireclay, and this should be sifted through a No. 4 mesh riddle and should then be moistened a little more than would be necessary if it was to be used in ramming a mold. If this mixture does not draw well, more clay can be added, as the clay will not affect the wax in any way.

Position of Pinion

The pinion should then be placed in a horizontal and level position with the missing tooth section in the center of the upper part. The core can then be rammed after first thoroughly cleaning between the teeth which are to be used as the guides, and which should be nearest the top.

The pattern is then placed in the bottom of the space between two teeth and held with lag screws, after which the core is rammed firmly to a point ¾ in. above the height of the tooth, as indicated in the drawing. The most convenient way to do this is to use an iron or wooden strip ¾ in. high on the top of the tooth. The core

should then be slicked from that height to the level of the opposite tooth. The idea of providing this extra height is to hold enough wax for shrinkage.

After the core is thoroughly rammed it should be carefully drawn by two men, using the end lag screws for the purpose. It should then be set carefuly upon a box wide enough to support it over the entire length. It is advisable to force a little sand under it in order to keep the core stationary. Two cores are necessary in the making of one tooth and the other core is made in exactly the same way as the first. When these are ready the operator should start at one end of a core and remove ¼ in, from top to bottom over the entire surface, as shown in the drawing. After this has been done the surface should be slicked

Fig. 22.—Pipe Facing Machine Open to Receive Pipe.

to make it smooth and marked so as to be sure of placing it in its proper position. It should be understood that this sand is removed from the side of the core which does not come in contact with the wax.

The object of this cutting is to make the mold slightly larger to take care of shrinkage of both wax and Thermit steel.

Placing Cores in Position

The cores can now be placed in position, one on each side of the missing tooth, making sure that the sides of the core from which the ¼ in. has been removed are resting tightly against the adjacent teeth. A weight should then be placed partly on adjacent teeth and partly on the core to hold it in correct position. The end can then be stopped off with fireclay mixed to the consistency of putty, after which the mold, i. e., the interior of core, can be filled with small pieces of wax about 1 in. square, after which melted wax can be poured in, thus filling up all spaces between the small pieces of wax.

Care should be taken not to have the wax too hot, as it is only necessary that it should be hot enough to run freely. If it is boiling hot it will tend to eat into the sand and make a rough tooth.

Placing Cores in Position

The mold should then not be disturbed until the wax has set, which will be from three to four hours after pouring. In the meantime, however, other work can be done, such as mixing sand for the mold, assembling mold box, etc.

If the pinion is shrouded, the wax pattern to provide the Thermit steel reinforcement on this shroud can be put on at the same time that the wax tooth is formed, it being only necessary to roll a long clay rod about 1 in. in diameter and lay it against the pinion 3 in. away all around from the space cut through the shroud, then back up with a board large enough to extend above the top of the tooth.

This board can be held in place with two "C" clamps, and luted with clay between board and cores on the inside so that the wax will flow to its proper level. (See Fig. 19.)

This work is all done in green sand and if care is taken while making the pattern for the new tooth with this method there will be very little finishing on the wax, thereby effecting a saving of about a day on each welded tooth. As an additional precaution, however, the steel template described in the first method for making wax tooth pattern should also be used in this case in order to make sure that the tooth is exactly the proper size, and in order to insure proper spacing.

When the wax pattern is finished, the mold box should be placed in position. This mold box should be wide enough to take in two teeth on each side of the tooth to be welded. Three staybolts should go through the box, as indicated in Fig. 20, to keep the box from spreading when ramming.

Mold

The mold box should then be firmly held to the pinion by means of two ½-in. thick strips bolted to the mold box. The lower strap should be about 3 in. wide and should encircle the lower shroud. The upper strap should be about 14 in. wide and should encircle the upper neck, just above the upper shroud. Both straps should be insulated from the pinion by ramming up a 3-in. space between strap and pinion with good sand mixed well with fire clay, which will not crush easily. This will then hold the box tighty to the pinion.

Now ram up the mold box, allowing for a preheating gate, a pouring gate and a riser in accordance with the general instructions for Thermit Welding. It is important that the heating gate, the inner end of which connects the pouring gate to the weld, as shown in Fig. 20, be extended to the very lowest point of the weld in order to make sure that this part be filled up with Thermit Steel.

When this is completed, construct a brick furnace around the exposed part of the pinion and about 2 in. away from the teeth. Next place a sheet iron casing around the exposed neck on top so that the casing rests on the strap which clamps the mold box. This casing should be 6 in. larger in diameter than the neck and about 4 in. higher. Now ram sand between the casing and the neck and cover the top with a layer of sand 4 in. thick. In this way the entire pinion is insulated.

The next step is the preheating. Place a burner at the bottom of the brick furnace and start with a very mild heat. This is to avoid heating the pinion too quickly, thus causing internal strains which might result in cracking the pinion. After the pinion has been thoroughly soaked with heat, the fire can be increased to a good sharp heat so as to bring the entire pinion to a good blood red or about 1200° F.

While the heating is in progress place an automatic crucible, of the proper size to hold the Thermit charge, in position over the pouring gate and charge with the welding portion of Thermit. In case of very large welds it is sometimes necessary to use two crucibles and provide two pouring gates in the mold.

Repairs of this kind usually require anywhere from 350 pounds to over 1,000 pounds of Thermit. It is therefore possible to use a higher percentage of punchings than with smaller welds, as there is enough additional heat to melt these punchings without re-

ducing the temperature of the steel sufficiently to interfere with the weld.

Pipe Welding

The Thermit welding proeess is adapted for butt-welding pipes end to end for piping in chemical and refrigerating plants and for high pressure, steam, hydraulic and compressed air pipe lines, where a permanent and non-leakable pipe is desired. The process is also applicable to the welding of superheater units for locomotives. These welded pipe joints can be made by the Thermit Process at less than the cost of installing

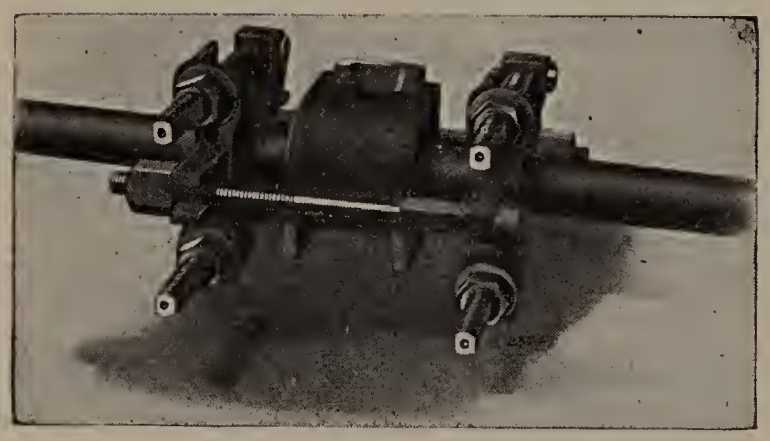


Fig. 23.—Mold Fully Assembled Ready for Weld.

ammonia flanged connections. The necessary apparatus is light and portable and may be easily handled and carried. The welding can be executed in the field as cheaply as in the shop and no outside heat or power is needed. Two men working together can under favorable circumstances weld an average of about 25 of the smaller sized pipe joints per day.

In making a Thermit weld the pipe ends are first faced very accurately and are then held tightly together by means of clamps. A cast iron mold is then placed around the pipe ends and the proper amount of Thermit ignited in a small flat bottom crucible or ladle. As soon as the Thermit reaction is over (about ½ minute), the contents of the crucible are poured into the cast iron mold. The liquid alumina or slag which floats on top of the molten mass in the crucible, naturally goes into the mold first and covers the inside of the mold and the outside of the pipes with a protective coating which prevents the superheated liquid steel, which flows in afterwards, from coming in contact with either. The heat of the entire mass, however, serves to bring the pipe ends up to a welding temperature at which time they are squeezed together by means of the clamps and a butt-weld effected. The entire Thermit mass can then be knocked away from the pipes and nothing will stick to either the pipe or the mold. A slight upset will be observed on the outside welded pipe but the inside diameter is in no way affected.

The entire operation is a simple one and the welds can be made by anybody after a little practice. The necessary apparatus, consisting of the pipe facing machine, pipe clamps, crucible tongs and mold are light and portable and can be carried to any point where work is to be done. As no outside power is required, the welding can be executed wherever the pipes are laid.

Detailed Directions

Preparing the Ends of the Pipe

Have the pipes cut with square ends before preparing them for welding. If the pipes are threaded it is necessary to cut off the threaded parts.

The pipes are then ready for the pipe facing machine.

Directions for Operating Pipe Facing Machine

First rotate the pipe facing machine hand wheel to the left, in order to back off the cutter as fast as possible, but not so far that it will be impossible to disengage the small jaw clutch. This will allow the cutter to be gradually fed forward during the pipe facing operation.

Then clamp the pipe facing machine to the pipe so that the end of the pipe to be faced is about ⅛ in. away from the cutter. Slide the handle of the machine inward so as to engage the jaw clutch and revolve it to the right so as to gently force the cutter against the pipe. If the cutter is forced too hard against the pipe, it will be almost impossible to revolve it by means of the ratchet handle, while if forced against the pipe too lightly the maximum speed of operation will not be attained.

Draw the hand wheel back so as to disengage the clutch and by means of the ratchet handle slowly revolve the cutter to the right, taking care not to revolve the cutter too quickly, as chattering is sure to result, especially as the cut becomes lighter. The speed of operation should, if possible, be uniform, and this is the main object of the ratchet handle which allows the uniform and continuous rotation of the cutter. There are places, of course, where the continuous rotation is impossible. This would be the case where the pipe was located close to a wall or where the pipes nearby would interfere.

As soon as the first cut has been taken the hand wheel should be moved into engagement with the jaw clutch again and the cutter again pressed against the pipe end. This operation should be continued until the end of the pipe is accurately faced.

After slight experience with the machine the operator can determine by the "feel" of the hand wheel when the pipe has been completely faced, but until such time the operator should back off the cutter to inspect the pipe ends. The chips from the cutter should be removed occasionally during the facing operation by means of a soft brush.

The steel casting through which the spindle operates is split and provided with an adjusting screw. This should, of course, be left as loose as possible, but if in operation, the cutter should feed in toward the pipe while being revolved, the adjusting screw should be tightened to prevent this "self-feeding." This tightening of the adjusting screw will clamp the brass sleeve and prevent its rotation unless intentionally rotated by means of the jaw clutch.

The "self-feeding" of the cutter is caused by the friction on the thrust face directly behind the cutter and a drop of oil should frequently be placed on this thrust face to prevent undue friction.

The cutter should be sharpened occasionally by means of a flat carborundum stone rubbed uniformly across the whole face of the cutter; two or three passes completely around the cutter will be sufficient. When the teeth of the cutter have become so flattened by sharpening that the stone does not seem to further affect them, the cutter should be reground, rather than to continue operation with it in this condition. In case at any time the cutter should become nicked, it should not be used until this nick has been removed by means of regrinding.

Making the Weld

In welding coils or bends, rig up suitable supports to keep the pipe in alignment. Where the pipes are close together in coils it is possible to spring out the pipe to be welded so as to permit of adjusting the mold and clamps.

Place one pair of clamp jaws around the end of each pipe about 4 or 5 inches from the end and tighten them securely by means

of the nuts and wrench provided for the purpose.

If the pipe ends have become tarnished after the facing operation, they should be brightened by using a fine piece of emery cloth or flat carborundum stone. In no case, however, should they be touched with a file or with the fingers on the faced surface.

Butt the ends of the pipe together and place the longitudinal clamp bolts in position. Draw up the nuts on these bolts by simultaneous applications of the wrenches supplied, being careful to see that the tension is equally divided so that the pipe ends butt together accurately all around their circumference. Draw up the bolts to obtain a good close fit between the abutting pipe ends. Turn the bolts one complete revolution.

Next place the lower mold casting under the pipe with the joint in its center and block up with wedges or earth to hold the mold castings securely in place. The upper casting is then placed over the joint which is now ready for welding. Place the crucible tongs on the ground conveniently in front of the mold and set the crucible in the jaws of the tongs. It is most important that this crucible should be thoroughly dried before using and if it is a new crucible it is advisable to burn a pound or so of Thermit in it and pour the contents out on dry sand as this is the quickest and most convenient way of drying the crucible. The operator should have the handles of the tongs toward him in order to pour the crucible when the reaction is completed. If double tongs are used, as is sometimes necessary with the larger sizes of crucible, a helper should stand opposite the operator in readiness to help pick up the crucible at the proper time and to assist the operator in the act of pouring.

In order that the sight may not be blinded momentarily by the incandescence of the liquid Thermit steel and slag, both men should wear blue glasses to protect their eyes.

The operator should then take one of the welding portion bags of Thermit and pour about one-half of the contents into the crucible. The remaining part can be placed in a hand scoop for feeding in during the Thermit reaction or can be poured from the paper bag directly into the crucible. Having, therefore, his portion partly in the crucible and the remainder in the scoop or bag, the operator should place one-half teaspoonful of ignition powder on top of the Thermit in the crucible and ignite it by applying a parlor match immediately after striking and before the head is burned off. This will ignite the ignition powder which in turn will start the Thermit reaction going. After reaction is well started the operator should add the rest of the Thermit from the bag or scoop trying to keep about one-half of the surface of molten material covered with unburned Thermit, and pouring in a steady stream without interruption until all the Thermit is in the crucible. He should then immediately grasp the crucible with the tongs, obtaining a firm grip, and pour the contents into the cast iron mold. The pour should be made the instant the Thermit has all reacted.

The crucible and tongs are then set aside and a short time is allowed to elapse for the Thermit mass to bring the pipe ends to a welding temperature. Shortly after pouring the operator should apply the wrenches to the clamp nuts and keep a constant pressure downward on these to determine when the pipe begins to soften. He should then wait from 10 to 20 seconds, depending upon the weight of the pipe, and then force the pipes together by means of 4 quarter turns (1 complete revolution) on the clamp nuts. It takes just about 10 seconds from the time the pipe ends begin to get soft until the time they are at a welding heat. (It usually takes about three-quarters to one-half minutes after the pour to bring the pipe ends to a welding temperature.)

After the clamps have been drawn up, the mold should be allowed to remain in place for three or four minutes longer, after which the clamps can be removed and the cast iron mold knocked away from the pipe by means of a hammer. The Thermit steel and slag will come away from the pipe with the mold and can be knocked out of the mold afterwards.

Care must be taken in every case that a complete welding portion be used, as only the full measure of Thermit will give a good weld.

It is advisable where joints are being welded in quantities to have several molds so as not to use molds continuously while hot. It is also advantageous to allow the mold with its contents of steel and slag to remain on the pipe for a considerable time before removing. If they can be left for from 10 to 15 minutes it is all the better.

By having several molds and a number of crucibles the welding can progress very rapidly and two men working together, one facing up the pipe ends with the pipe facing machine, and the other following and doing the welding, can make an average of about 25 pipe joints per day on the smaller sizes of pipe.

Welding Vertical Pipe

The foregoing instructions apply to welding pipe in the horizontal position. Vertical

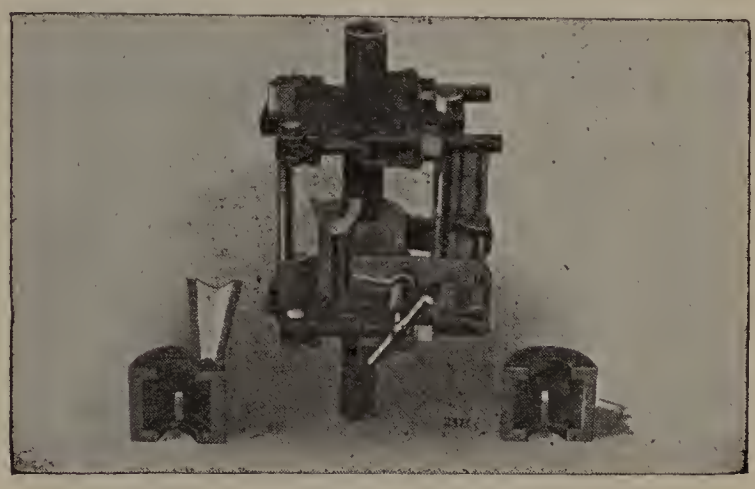


Fig. 24.—Welding Vertical Pipe.
Center View Shows Mold and Clamps on Pipe Ready for Welding. Side Views Show Two-Part Mold with Vertical Partition to Divide Thermit Steel Collar.

pipe, however, can be welded in essentially the same manner, but a special mold is required. The mold is constructed in such a way as to divide the Thermit steel collar into two parts, so that it may be readily removed from the pipe on the completion of the weld. The mold also has a different type of pouring gate as will be seen from Fig. 21.

Thermit Rail Weld

Briefly, the Thermit rail weld is accomplished by pouring the super-heated steel obtained from the Thermit reaction into a mold surrounding the rail ends at the joint. This fuses with the base and web of the rail as well as with the lip and one side of the head. An insert cut from a rolled section of similar analysis to that of the rail itself is placed between the heads at the running face and the lower part of this insert is melted into the Thermit steel. The mold is so constructed, however, that the head of the rail and top part of the insert are not melted but are merely heated to a welding temperature. The sudden expansion of the rail ends caused by the heating ac-

tion of the molten Thermit steel surrounding them forces them together with tremendous pressure and thus effects a pure butt-weld on both sides of the white-hot insert. When this has been accomplished the running face is ground to a true surface and the surplus metal ground out of the

Fig. 25.—Hammering Insert Between Rail Ends.

groove. The weld obtained in this way is so perfect that it is practically impossible to detect its location after the rails have been paved in.

In practice the welding is best done after the ties have been concreted. If the welding is done before the concreting, it it somewhat difficult to keep the rails in perfect alignment and to proper surface after the temporary splice bars have been removed. The rails are spaced with gaps at joints varying between ¼ in. and ⅝ in. in width, depending upon the temperature at the time of laying and brought to proper surface and alignment, care being taken to keep the rail ends a trifle high. This slight raising of the rail ends has been found advantageous in practice, as it assures proper alignment and surface after grinding.

A rail steel insert is placed in position between the heads of the rails, and a two-part

Fig. 26.—Ramming Mold Box Halves.

sand mold clamped in position surrounding the joint. These are rammed in advance over an aluminum pattern, the dividing line at the mold being along center line of the web of the rail.

The pattern is so constructed as to form an opening around the rail ends in the shape of a collar in which the Thermit steel is poured. Pouring gates and risers are also provided for in the mold in a similar manner to molds used in ordinary foundry practice. An additional opening is provided near the bottom called the heating gate, and through this the rails are heated red hot and the molds dried out previous to pouring in the Thermit steel. Provision is made in the construction of the mold and in its application, so that it automatically becomes sealed tight when clamped to the rails.

Preheating

With the molds in position, the next step is to preheat the rails at the joint to a good red heat, at the same time drying out the mold. This preheating is one of the most important steps in a Thermit welding operation as it serves to expand the rails for a considerable distance on each side of the

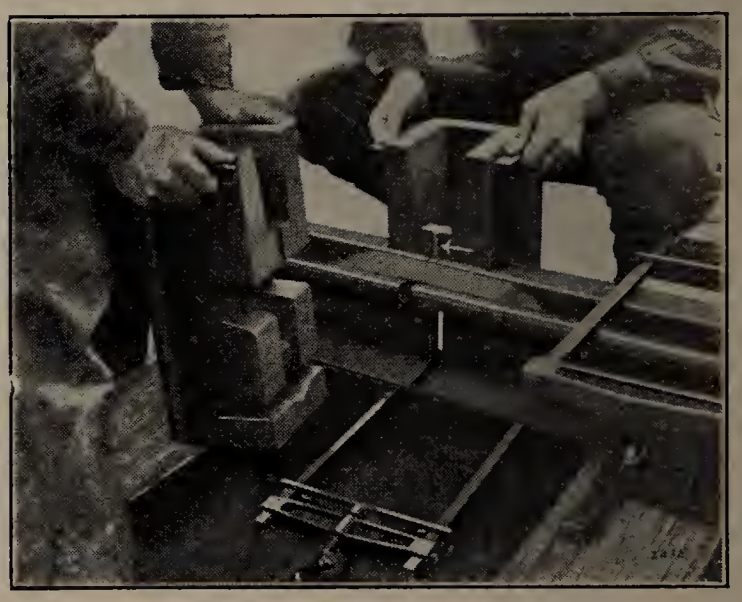


Fig. 27.—Applying Molds to Rail.

joint, thus offsetting the contraction of the Thermit weld when it cools and leaving the welded track free from the shrinkage stresses which would otherwise be present.

For this particular operation a light weight double burner preheater is used. It can easily be moved from one joint to another. A vaporizing apparatus enables kerosene to be used instead of gasoline, thus securing the benefit of the greater heating value of this fuel as well as its lower cost.

This machine will, in particular, permit the welding of a few scattered joints almost as economically as when larger quantities are being welded. For repair work and for the welding of compromise joints, therefore, the light weight preheater offers special advantages.

Completing the Weld With Thermit

A specially designed magnesite lined crucible is next swung over the pouring gate of the mold and filled with the welding portion of Thermit. (For description of the Thermit reaction see Directions for General Welding.)

The steel produced by the Thermit reaction enters the mold on the lip side of the rail and thoroughly melts and amalgamates with the lip as well as with the web, base and one side of the head. No Thermit steel is allowed to touch the running surface of the rail, as the steel insert closes up the space between the rail ends except for a small opening of about ¼ in. from the outside of the head. The under part of the insert is thoroughly fused with the liquid steel and becomes a part of the fusion weld.

As explained previously, when the metal for the weld is poured, the expansion thus produced creates sufficient pressure on each side of the insert to thoroughly butt weld it in position so that at the end of the operation the entire rail is welded into one homogenous mass.

One of the principal advantages of this type of weld is the fact that it depends on a predetermined chemical reaction which is always uniform. The success of the reaction is assured by the fact that every Thermit welding portion is weighed out

separately for each rail section to be welded and in just the proper quantity to obtain a perfect weld on that section.

Thermit rail welding operations have also been very much simplified by the perfec-

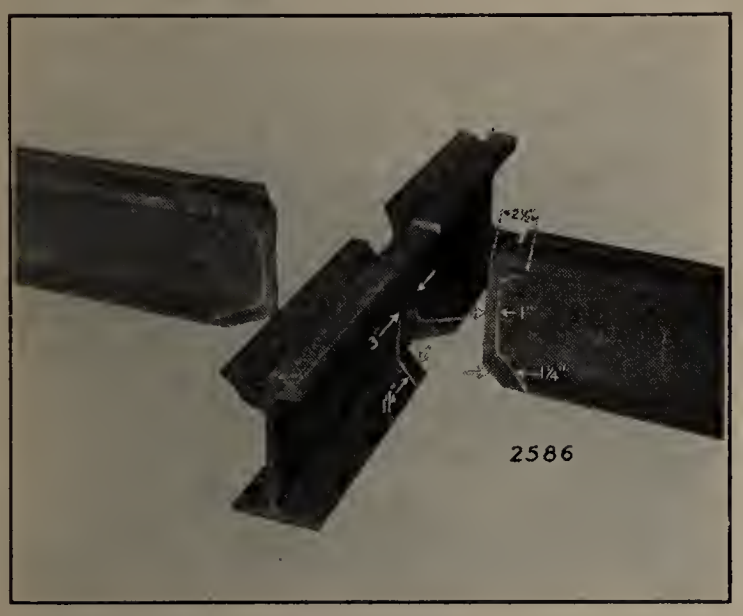


Fig. 28.—Assembly for Welded Frog.

tion of a new thermit mixture which develops such heat that the additions can be mixed cold in it instead of being put in a can and preheated.

After the weld has been poured, the mold should be left undisturbed for a short time. The mold boxes can then be removed, the metal left in the risers and pouring gates cut off by nicking with a hammer and chisel and knocking off. All sand, etc., is cleaned from the rail in the vicinity of the weld and the joint is ready for grinding.

As the steel insert is left a trifle higher than the rail section, this excess metal must be ground off, together with the excess metal left in the groove and on the outside of the head where the riser is removed.

This grinding can best be accomplished by means of the Thermit Rail Grinder, which was designed specially for the purpose. It

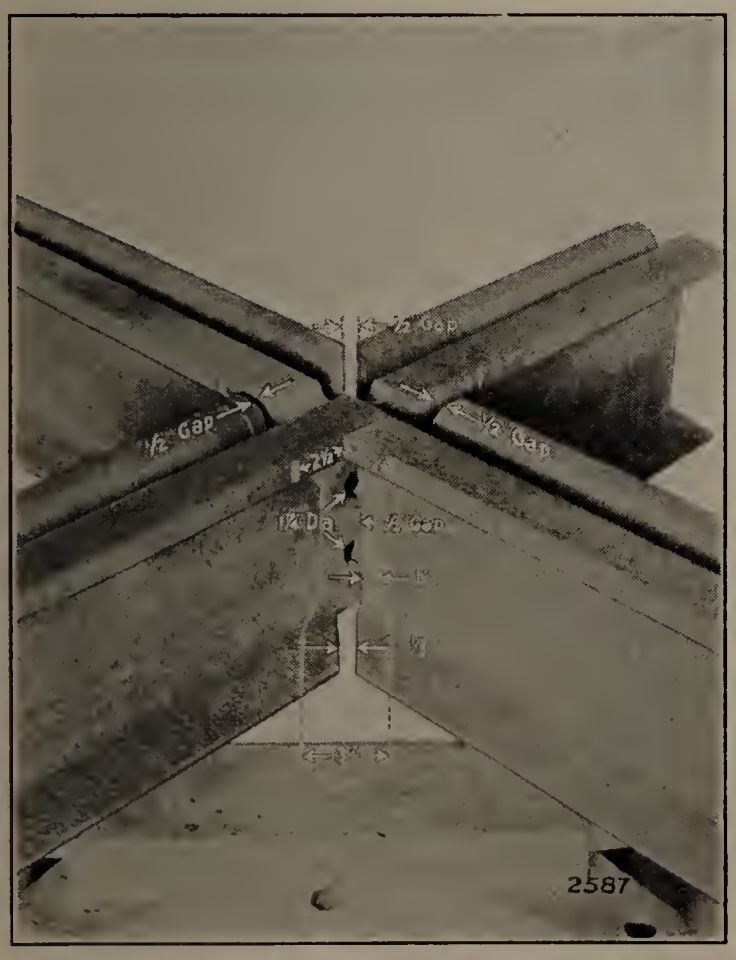


Fig. 29.—Frog Ready for Welding.

possesses advantages over most other rail grinders in the fact that the weight is concentrated over the grinding wheels so that a deeper cut can be taken. It also has attachments permitting of grinding in the groove of the rail and on the gauge.

It is generally agreed by engineers engaged in the construction and maintenance of street railway track that the rail joint is the weakest part of the structure and that usually the life of the rail is dependent on the life of the joint, as it usually results that the joint is in such condition as to compel the removal of the rail long before it is worn out.

The Thermit rail weld is designed to remedy the above mentioned condition by embodying the following features:

(1) It is fully as strong as the unwelded portion of the rail, in tension, in bending, in repeated impact, etc.;

(2) There is no change in section to interrupt the elastic wave and

(3) its electrical conductivity is the same as the rail itself and this electrical conductivity will not depreciate with time.

Since the present Thermit rail weld was first introduced in 1912, it has steadily grown in popularity and hundreds of thousands are installed throughout the country at the present time. The only reason that it has not been used to a greater extent is because until recently the cost, as compared with other joints on the market, was high.

Fig. 30.—Wax Pattern for Welded Frog.

During the last few years, however, as the result of extensive research and development work, improvements in methods have been perfected which have reduced the cost of welding to a point where it is now no more, and sometimes less, than any other type of joint.

When used in conjunction with new style self-luting mold boxes, which require no hand luting, the operations merely require clamping the molds to the rails, preheating and pouring. The preheating takes from twenty minutes to a half hour per joint and the number of joints which can be welded in a day is only limited to the number that can be preheated. When two joints are preheated at a time, there should be no trouble in making thirty-five to forty joints per day with a comparatively small gang.

The simple and portable character of the welding outfit, including the grinder, is a strong point of merit, as one service car will carry all the equipment, or, if desired it can be hauled on its own wheels.

Compromise Joints

Probably no problem connected with street railway work causes more annoyance and expense to the "way department," in proportion to its magnitude, than the proper maintenance of compromise joints. While at first thought it might appear that the number of these joints on the average street railway system is so small as to be practically negligible, it is a fact that actually there are a great many more than would be reasonably expected. The reason for this is not difficult to find. Owing to the very rapid development of electric traction, with the consequent increase in the weight of rolling stock and speed of operation, it was necessary to increase the size and depth of the rail accordingly. Requirements of modern pavement also demanded frequent changes in the design of the rails, so as to offer as little interference with vehicular traffic as possible and still provide a good track. The result is that there is hardly a street railway system in the country that has not a great variety of sizes and types of rail in its track and wherever these various sections come together a compromise joint is necessary.

When it is considered that for every change of section two compromise joints on single track and four on double track are necessary, it will be readily understood that, on the older street railway systems particularly, there must be a great many of these joints.

Mechanical joints have not proved satisfactory, as the plates are seldom accurate and it is exceedingly difficult to obtain either

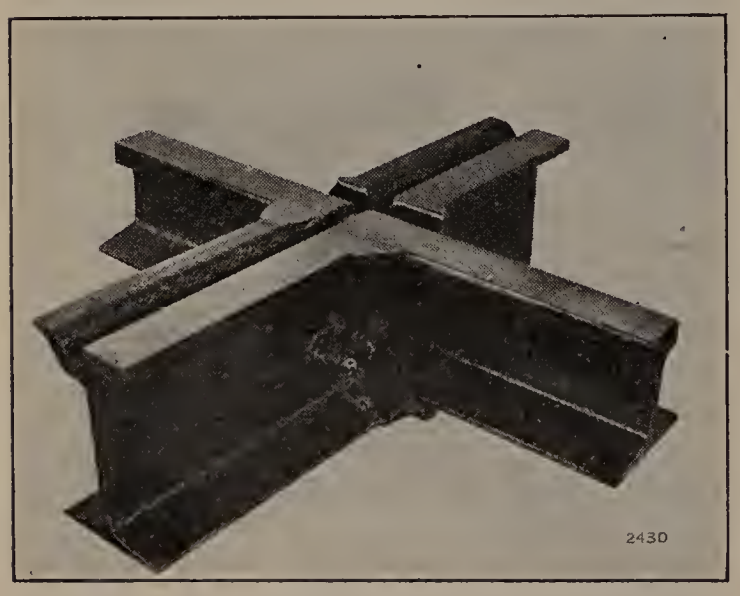


Fig. 31.—Thermit Welded Frog.

a forged or cast plate which will hold the rails to gauge or surface. Another serious objection is the difficulty of obtaining a satisfactory bond. The Thermit rail weld, however, will overcome these objections, with the added advantage that the welds can be made by the street railways themselves either in their shops or in the street and can therefore be had at a minutes notice and without the necessity of carrying a stock of special plates or special cast joints designed for this purpose.

The weld can be made in practically the same way as described for welding rails but where only a very few joints are to be made the cost of wooden patterns can be eliminated and a wax pattern used instead. In this way a few joints can be welded quickly and economically.

Thermit Welded Frogs

One of the most striking developments of Thermit welding has been the remarkable spread of this process for welding sections of rail to form frogs and single and double track crossings. The advantage of boltless, jointless, Thermit welded tracks are particularly noticeable in the case of special work because Thermit welded frogs can be constructed at only a fraction of the cost of manganese or other special work. Furthermore, service tests of over five years, under heavy traffic conditions, in Milwaukee, In-

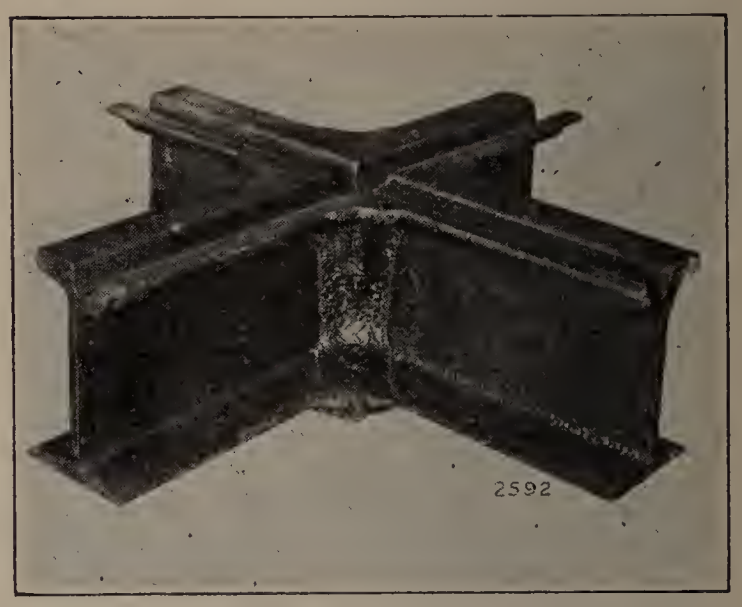


Fig. 32.—Thermit Welded Combination. See Rail and Groove Rail Frog.

dianapolis, Youngstown and other cities have conclusively shown that Thermit special work has held its own in comparison with other installations costing two or three times as much; in fact it has outlasted manganese insert frogs installed in the same place and subjected to the same service.

Thermit welded special work can be made in the railway shops, and the completed layout then transported to the street and quickly set into position and welded to the adjoining rails with minimum delay to traffic. In the case of double track crossings, two halves of the crossing can be constructed in the shops and the projecting arms of each half later welded together in the street. An installation of this sort possesses many advantages over bolted or manganese special work for the reason that the welded crossing can in turn be permanently welded to the adjoining rails, making an absolutely rigid and substantial installation with nothing to work loose. This is a particular advantage, because the presence of mechanical joints in or adjacent to the special work is responsible more than anything else for premature breakage and loosening of frogs. With a fully welded installation of the kind mentioned above no conductor cables are required, as all joints will have the full electrical conductivity of the rail itself.

Cast Iron Repairs

The Thermit process, while entirely suitable for the welding of cast iron, cannot be used on all cast iron welds owing to the difficulty in some cases of allowing properly for the shrinkage of the metal in the weld when cooling. Thermit steel contracts twice as much as the cast iron of the parts to be welded, so that as a general rule if the length of crack is more than eight times the thickness of the material the difference in shrinkage along the line of the fracture will cause small hair line cracks to appear in the Thermit steel perpendicular to the line of the fracture. These cracks however, being always perpendicular to the line of the weld are usually, therefore, of little consequence and do not interfere with the strength of the weld. In all cases, therefore where the length of a break is less than eight times its thickness cast iron Thermit welds are very satisfactory, although naturally a little more care must be exercised in

allowing for the contraction of the weld as the cast iron part lacks the elasticity which a similar steel part would have.

Care should be taken in preheating for cast iron welds not to heat the sections too hot, a dull red is sufficient. One should be careful, however, to keep the heat going until the mold is thoroughly dried out.

Cast Iron Thermit

The mixture of Thermit for the weld, however, should be different from that recommended for wrought iron and steel, and for this purpose a special mixture, known as Cast Iron Thermit, is recommended. This consists of plain Thermit with which is mixed 3 per cent ferro-silicon 50/50 and 20 per cent mild steel punchings; i.e., to every 100 lb. of plain Thermit is added 3 lb. of ferro-silicon and 20 lb. of punchings. This gives the best results on cast iron and produces a soft and homogeneous metal in the weld.

Cast iron welds are more difficult to machine than welds in wrought iron and steel, because cast iron contains over 3 per cent. carbon and when fused with the Thermit steel the resulting metal at the weld is naturally a high carbon steel. This steel is considerably stronger and less brittle than cast iron but is machined with difficulty. The finishing of cast iron welds is usually accomplished by grinding.

If there is any doubt as to the feasibility of making a cast iron weld, the Metal & Thermit Corporation will be glad to advise the customer on receipt of a blue print or sketch showing the location of the fracture, and giving full dimensions.

Casting Long Sections

Ingot stripper plungers are extremely difficult to cast, owing to the fact that the cylinders while 18 in. diameter and 25 ft. or more long, have walls only 1 in. thick. Inasmuch as it is almost impossible to obtain a perfect core and then anchor it so as to prevent floating the thickness of the metal is often reduced on certain sides, thereby weakening it and resulting in frequent breakages.

It has been found, however, that these castings can be made very much easier and of more uniform thickness by casting each cylinder in three separate parts of about 10 ft. each, instead of in one piece and then welding the parts together by means of Thermit. All three welds can be machined off at the same time and as the outside of the cylinder must be machined anyway, practically no more machining is required than if the plunger were cast in one piece. Plungers have been successfully welded in this manner for the past ten years and the welds have stood up perfectly in service.

In the same way locomotive frames of unusual length and other long sections which are difficult to cast all in one piece can be cast in shorter lengths and these sections Thermit welded together. By using this method smaller foundries can undertake this work. The number of parts to be welded will depend on the size of the foundry and available mold and pattern facilities.

Thermit welding may also be similarly used for building up shafts and other sections in inaccessible places such, for example, as logging camps, where inadequate means of transportation makes it difficult to convey sections of unusual length. The Thermit process may also be advantageously used in such places as mines, where limited space necessitates the assembling of a section from smaller units. In the case of a crank shaft, instead of shrinking on forgings which are likely to work loose, the parts can be welded together, thus forming one rigid piece.

BOILER WELDING*†

THE use of Oxy-Acetylene and Electric Welding processes for boiler welding and cutting is by no means new, therefore, the purpose of this chapter is not intended to introduce a new process, but to show practical and experienced points, how to make practical welds on boiler plate as well as those parts which should not be welded.

Advantage of Welding Over Riveting

The riveting process consists of lapping two sheets about two or three inches together, riveted and caulked at the edges. In heating a riveted fire box, the water will not protect the lapped joints exposed to the fire; nor will heat penetrate to the water side of the lapped joints. With the riveted joints we have to contend with two thicknesses of plates, rivet and the mill scale between. We all know that the mill scale, or mill oxide, is a non-conductor of heat and is acting as a barrier between both sheets. The consequences are that the lapped portions of sheet that is exposed to the flame will crack from the rivet hole to the edge. At this stage, it will begin to leak more or less and the steam pressure will act as a wedge and force its way between the lapped joints and thus crack the next rivet hole, and so on until the top seam exposed to the fire is defective. However, the greatest evil is when these fire cracks begin to leak with more force and the escaping steam that reaches the adjoining solid metal will burn or peel off the sheet, until it becomes as thin as paper, and is then condemned by the Boiler Inspector. Thus many a good boiler with only a small portion of steam burnt plate has been scrapped because the riveting process could not reclaim these defects.

Obviously it is necessary to stop the leak from fire cracks, or other cracks, before the adjoining plates become steam burned. The only remedy the boilermaker has is the caulking tool, but it acts on a boiler the same as toothache drops will act on a well decayed tooth. While it may in some cases stop the leak for a short period, sooner or later it will leak with greater force.

The only improvement that can be made with the riveting process, is to grind off the mill scale between the lapped joints and fit both sheets before the riveting, the same as a ground valve seat, but who is the boilermaker who will take the time and trouble to perform this work? In many cases one can see lapped joints sprung away about ⅜-in. or ½-in. forced together with bolts and then fastened with rivets

The Welding Process consists of joining two plates by butt welding the edges and when finished the joints will be seamless and will have throughout the plate a uniform thickness. In heating a welded fire box the water will protect the sheet on its entire surface. It eliminates all the evils of fire cracks, steam burnt plates and caulking. It decreases the coal consumption and facilitates steam generation.

In some railroad fields the present application of welding in fire boxes is performed with more or less success. Lack of proper instruction, lack of proper supervising, lack of ambition on the part of some operator is a good deal responsible for the slow progress made in boiler welding. In commercial fields, however, there is more ambition among welders, because they are required to guarantee the job. In many instances the railroads or other institutions, employ a well known and well rated commercial welding firm, to do their boiler welding upon a guarantee basis, and in these fields this process is really making good progress, and is practically the backbone of the present welding industry.

Important Tools

A boiler welder, like any other mechanic, must have a knowledge of the tools he uses. The boiler welder must understand his flame, the same as an artist or painter understands his colors. An Oxy-Acetylene flame for boiler welding purposes must be clear, without any excess of oxygen or acetylene, or in other words it must produce a perfect combustion of gases. An excess of oxygen means burning, or oxidizing the metal; an excess of acetylene means blow holes and carbonizing the metal[1]

Furthermore, an excess of oxygen will exaggerate the melting of steel and the molten metal will run in parts where it was not intended. An excess of Acetylene will cause adhesion and cause the metal to be hard and brittle.

To be able to produce a clear neutral flame it is necessary to have a good torch, clean tips and good regulators. It is always best to use a well made torch with a 45 deg. head. The tip of the torch should be clean at the end without carbons or burrs. Some boiler welders prefer a new tip for boiler welding and then keep it only for this kind of work. Any foreign substance adhered to the extreme end of tip, or burrs, will cause a rigid and a one sided flame, and regardless of the valve regulation, it will be an oxidizing flame.

The next important tool for a boiler welder is to be sure to use good regulators, that will release a constant and uniform pressure. Creeping regulators will produce an oxidizing and carbonizing flame, and should not be used for boiler welding. Some boiler welders keep a new set of regulators for boiler welding only, and will use other regulators for cutting or heavy cast iron welding.

If the regulator creeps, then most likely the seat is cracked. In this case remove the back cap of regulator and put in a new seat, and the regulator will be as good as new. The same must be of the same material as the old one and can be purchased from any apparatus manufacturer or jobber.

If a generator is used there is no danger of not supplying the tip with sufficient acetylene, but if compressed acetylene in tanks is used do not try to empty the contents of tank, because below fifty pounds of pressure one cannot secure sufficient gas delivery for the tip. Furthermore, it will draw out the acetone and will decrease the regulated proportion of acetylene. The result is that the green cone is getting thinner and longer and loses its heat units.

Some welders are then increasing the oxygen pressure so as to obtain more heat, but this will only burn or oxidize the metal. However, the fifty pound pressure left in the tank must not be wasted. One can use it for cutting purposes or sheet metal welding.

It is best to use the largest tanks. While the 100 cu. ft. tanks might be used in emergency, do not use the small 40 or 60 cu. ft. lighting tanks for boiler welding.

If a generator is employed, one must use clean water every time a charge of carbide is put into a generator—this must not be neglected if one desires clean acetylene. Furthermore, the capacity of the generator should not be less than thirty pounds of carbide.

Points to Operators

A boiler welder must not be a boiler maker any more than an automobile driver must wear a uniform. However, the oper-

**Written by B. K. Smith for The Welding Encyclopedia.*

†See "Rules and Regulations."

[1]See "Neutral Flame," "Carbonizing Flame," etc., and "Flame Chart."

ator must be familiar with boiler construction so as to know the names of various parts of boilers. Boiler welders must also learn to have perfect fusion of metals continuously and to control the metal with the flame and welding rod. It is essential that the welding be done at a steady speed, and not play the flame on certain parts longer than necessary. It is also necessary to do the welding without interruption until the job is finished. It is best for the operator that before he commences to weld to figure out in his mind the whole welding problem and then follow the various operations in proper order until the job is complete. Guessing or depending on good luck must be eliminated in boiler welding, and the operator must depend on cold blooded facts. If he has the welding problem classified in his mind, then he will perform his work with more enthusiasm and insure success. If he has not these qualifications, it is best for him, his patrons or employer that he lay off boiler welding and save his reputation.

Fig. 1

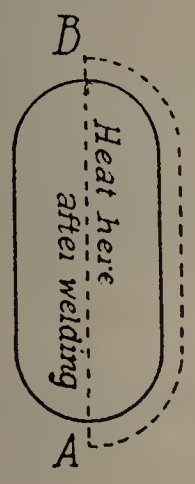


Fig. 2

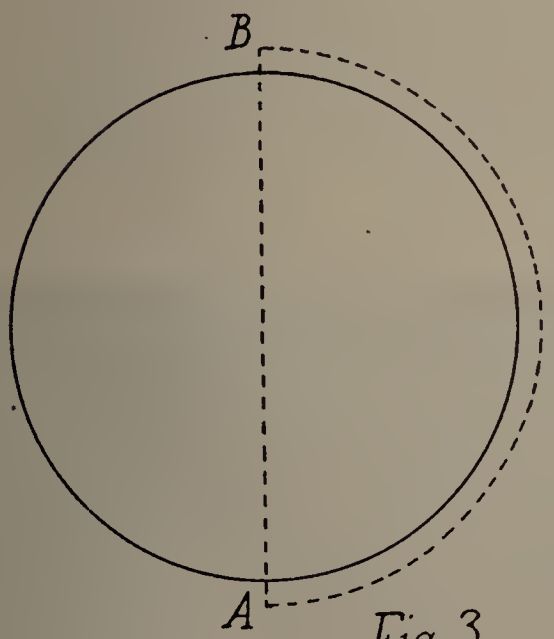


Fig. 3

Safety First Points*

Do not weld stay bolts to the sheet.
Do not weld crown bolts to the sheet.
Do not weld on top of rivet heads.
Do not weld on caulked edges.
Do not weld on barrel of boilers.
Do not weld any portion of boiler which is not stayed with bolts or rivets.
Do not apply or weld lapped patches for welding.
Do not use home made acetylene generators.
Do not use leaky or patched hose.
Do not place oxygen or acetylene tanks inside of boiler or on top of running board.
Do not cut plates on top of oxygen or acetylene tanks.
Do not use greasy gloves when welding, or cutting, boilers.
Do not weld sheet to mud ring when it is riveted.
Do not weld crack in fire box if crack is longer than 8 inches.
Do not weld on top of oxy-acetylene cutting edge, clean up the edges with hammer and chisel before welding.
Use goggles when cutting and welding on boilers.
Do not use acetylene in drums while in a flat position.
Do not keep matches in pockets. Use a gas lighter because it is safer and cheaper than matches.

*See "Rules and Regulations."

Welding Rods

It is very important to use the proper welding rods for welding boilers, since the welding rod is relied upon to join the two edges of boiler plate. A clear soft steel rod has been found entirely satisfactory for this work. Furthermore, it is best to test these rods before they are actually used on boiler welding. As the average welding shop has no testing machines, the author would recommend the following test:

Heat to red in the middle of the rod, then bend the rod up and down. A good rod will bend four or more times before it will break. An improper rod will break at the heated point on the first or second bending.

When welding, the end of the rod should be bent to about the same degree as the head of the torch.

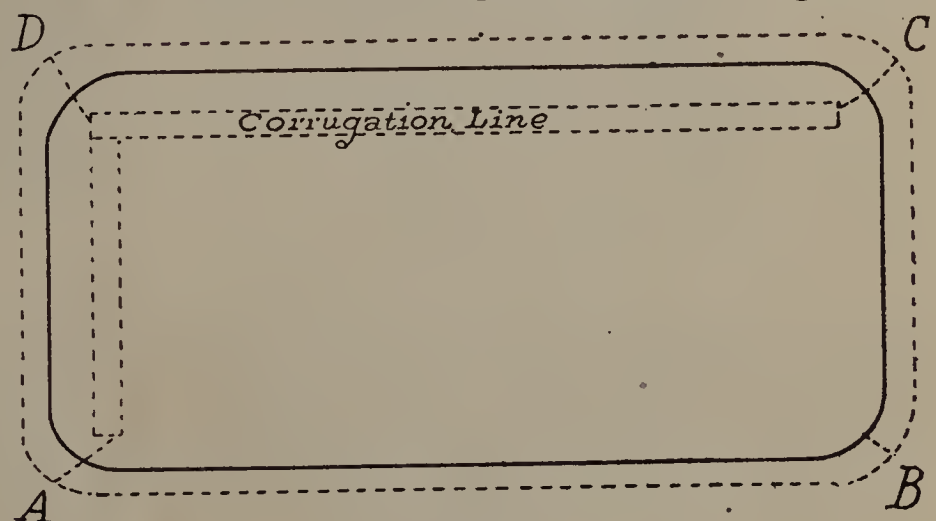


Fig. 4

Preparing[2]

The success of a welding job depends a great deal on how it is prepared, therefore, it is advisable to take good care in the preparation of any job in the fire box. For this purpose one must have on hand steel wedges, C clamps, bolts, stay bolts, etc.

To bevel the plates to a 45° angle, one can use an air hammer and chisel, and when this is not available, the cutting torch can be used, but it is necessary to remove the oxide deposits on the edges. It is also very important to anneal the edges before welding to about two inches wide. This can be done with the welding torch and welding should not be commenced until the edges are reasonably cool.

In order to weld throughout the thickness of the plate it is necessary to prepare the edges so they will be, and always stay, separated from $\frac{1}{16}$ to $\frac{3}{16}$ of an inch. Do not weld plates when edges are overlapped. The steel wedges will prevent overlapping to a certain extent.

In setting in a patch or a whole sheet it is necessary to prepare it so the edges will run level always. To keep them in place during the welding operation one can use the "C" clamps below at the mud ring, bolts through both sheet and counter tightened with stay bolts from the outside sheet.

If through some error or negligence

[2]See "Beveling."

sheet would buckle toward the fire side, one can heat the edge and hammer it back level with the opposing edge. If same is buckled towards the water side one can screw in the stay bolts further until the edges are level. Under no circumstances weld the edges while some portion of it has buckled in or out. Such work is not permanent and will crack sooner or later.

Expansion and Contraction

The every day problems of expansion and contraction on boiler welding are great and interesting and yet simple to solve. If one would bear in mind that metallic parts will expand or increase in volume under the action of heat and on cooling they contract or return to their original volume, there would be no trouble to solve this problem. The main trouble is that some operators get in their minds that, while mild steel is ductile, it should be less feared because the metal in itself possesses the property of elongation.

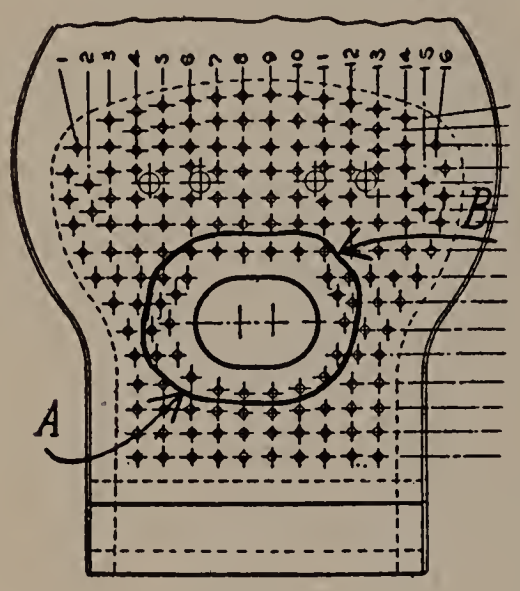


Fig. 5.

The boiler welder should not expect that the metal will give or that a little strain would not hurt the weld for three reasons: First, the welding line or the filling rod that was melted in the "V" is nothing but a cast metal. This metal, like any other metal after fusing or melting, will shrink a little on cooling, the same as castings that are poured in moulds at the foundry. For this reason the foundry man will make the mould large enough so that it will take care of the shrinkage on cooling and yet give him the right size casting. But when one melts a long line of say ⅜ cubic inches of metal and same is supposed to hold two plates, it will shrink on the same proportion as a large poured casting on cooling. If one or both ends of the two welded plates are free to expand and contract on cooling, there is no fear of any strains left in the weld, but if both plates are rigidly tight with rivets or bolts, then one can be sure that there will be a strain left in the weld, or as it happens in most cases, it will break at the weld on cooling.

Second—That no human being can measure or know definitely how much of a strain is left in the metal. It may be very little or may be to the breaking point.

Third—That almost in all cases an intelligent welder can find a solution of how to take care of his expansion and contraction.

The best device known by the author is the corrugation feature. In a fire box, where a patch, side sheet or door sheet is set in for welding, it is necessary that a corrugation be set in by the boiler maker close to the welding line, about ½ or ¾ inch deep. This corrugation will not only give flexibility in the weld and its vicinity, but will enable an operator to reweld any defect in the future without taking any stay bolts off, using that same corrugation. The expansion and contractions of the welding line will be divided equally between each row of stay bolts into the corrugation.

We will now discuss various problems of how to take care of expansion and contraction. The most common defects in a fire box are fire cracks. Suppose we have a longitudinal seam with fire cracks, and the sheets are in good condition. Some welders will weld the lapped seam, cracks and rivet heads and deposit about a hundred pounds of filler rod on the seam, and when finished they will find, about every eight or ten inches, vertical cracks about three inches long crossing their weld. These cracks they will finally try to calk, but the job is no good.

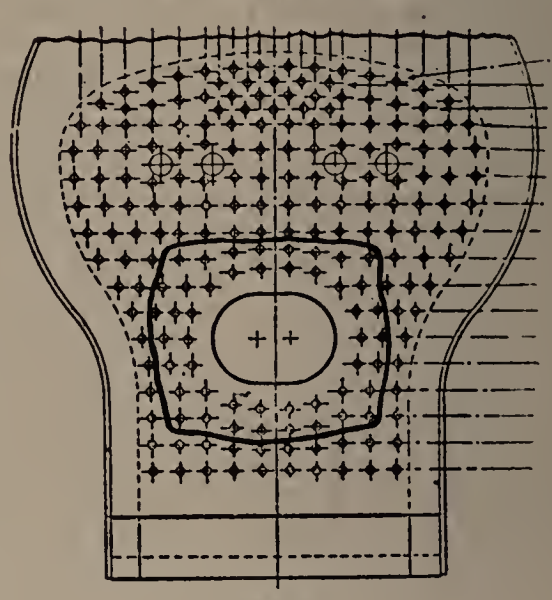


Fig. 6.

The proper method in this case is to cut with the cutting torch a straight line across the rivets. Remove both laps from each plate and if necessary cut the inside lap through the rivet holes, so one can fish them out through the mud rings. If there is a sort of radius bend in the sheet, one can proceed to level both sheets and weld them together. The radius bend on the sheet will give sufficiently in contraction,

Fig. 7.

but if sheets are straight and there is no bend and they are rigidly tight with stay bolts and rivets then it is necessary to heat the edges two inches at a time and with a machinist hammer bending in one edge at a time to about 35° as per Figure 1, thus forming a curve which is practically the same as a corrugation. On cooling the bend at the curve will straighten a little and leave the weld without a strain.

If fire cracks are to be welded on flue or

door sheets, cut the same as above in the center of rivets as high as necessary; remove the laps, level the edges, and weld from bottom up. About every six inches of welding it is necessary to heat to red the flanged portion which is next to the weld. In doing this the curve or the bent portion of the flanged sheet will give sufficiently on contraction so as to leave the weld without a strain.

The second common defect in a fire box is cracks in the sheets between stay bolts.

Fig. 8.

In this case remove the stay bolts affected from one end of crack to the other. Heat the edges to red and bend the edges towards the water side, the same as Figure 1. The shrinkage will be taken care of from the bended curves and in most cases the welder will find that these curves will straighten out entirely. Such cracks will never happen in a horizontal line, but always vertical and the welding should be done from bottom up. If such cracks extend over eight inches then it is best to

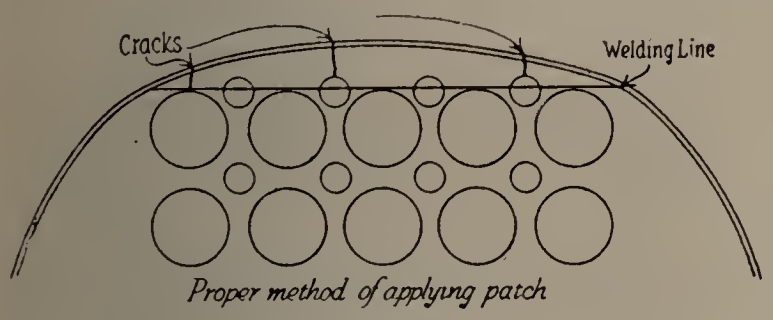


Fig. 9.

insert an egg shaped or oval patch as per Figure 2. Then heat this patch in a forge and dish it out towards the fire side about ¾ inch deep in the center. Set the patch in, holding it in place with a couple of bolts. Then drive four steel wedges, two on the side and the other two on top and bottom. Commence to weld from A to B. Let it cool for about 20 minutes, then weld from B to A. After the welding is finished heat the center line of the patch from bottom up. That extra material that formed the dish in the patch will give on cooling and eliminate any strain in the weld.

Whenever one sets in a patch on a solid sheet, do not cut the patch with sharp corners, but always cut them as round and as long a radius as possible. Sharp corners will cause cracks on the sheet.

Figures 2, 3 and 4 are most desirable patches, but a square is unsatisfactory on account of the sharp corners. Patch on Figure 3 should be dished and the welding performed in the same order as in Figure 2. Patch on Figure 4 should be corrugated on two sides from A to D and D to C. Then insert about every six inches apart a steel wedge. Weld from A to B and then from B to C. It is necessary then to wait about twenty minutes for the weld to cool; then weld from A to D and from D to C. On the last two welds it is well to heat after every six inches of welding on the corrugation, so as to give the latter a better chance to give a sufficient volume of metal towards the welding line on cooling.

Another common defect in a fire box is cracks on the flange of a door hole, on the

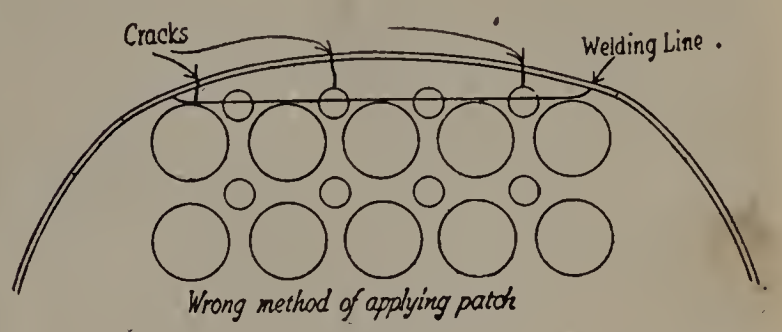


Fig. 10.

door sheet and fire cracks from rivet or patch bolt hole to the caulking edge. Some of these cracks are visible, others are not, but when one attempts to weld the visible crack, three or four more cracks will open up, and so continue indefinitely. Furthermore, on account of the patch bolts or rivets that are joining the door sheet with the back head sheet being so near these cracks it is not advisable to attempt to weld these cracks if a permanent job is desired. In this case it is always best to cut out the defected portion, as per Figure 5. If there are fire cracks on the back head flange in addition to the cracks on door sheet flange; then cut out both sheets as per Figure 6. Then flange out two patches, which we call door collars, and have both flanges butt on the edges. Some welders prefer to lap weld the inside circular weld. The disadvantage

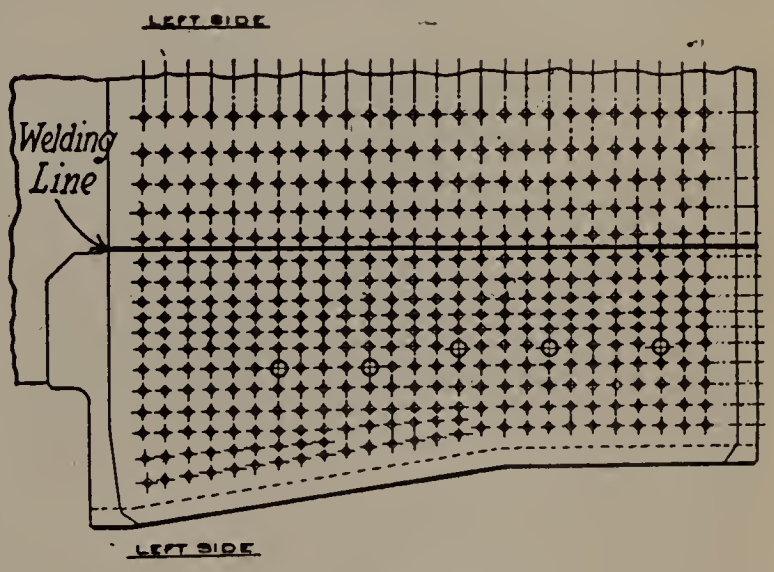


Fig. 11.

of such welds is that the heat during the welding operation will open up the inside lap and form a perfect mud pocket all round the fire door hole. Such mud pockets must be avoided because they cause boiler blisters, therefore, all welding must be butt welded. Then there are no pockets left in which mud will accumulate.

The best method of welding in door collars is to slightly flange out both bevelled edges before welding, about ⅜ of an inch. Then set patches in, holding them in place with bolts and securing the openings of the edges with steel wedges. Separate the lower edges from A to B about $\frac{3}{16}$ or ¼ inch. Separate the upper edges from B to A about $\frac{1}{16}$ inch. Then commence to weld the lower

edge first from A to B. Stop for about twenty minutes and continue to weld the upper edge from B to A. The reason one should have a larger opening at the lower edge is because, on cooling it will contract and increase the opening at the upper edge to about ⅛ of an inch.

Figure 6 is an improper method of setting in a door collar for welding, on account of its sharp corners.

Figure 7 shows after the defective door collar was cut out, and Figure 8 shows the same after new door collar was welded.

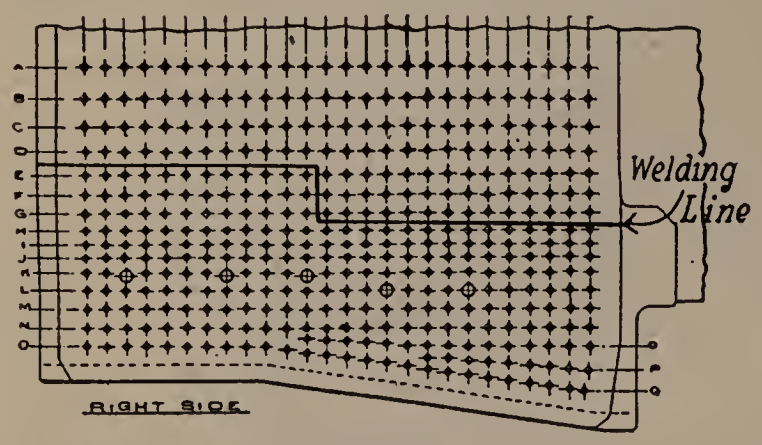


Fig. 12.

Occasionally one finds cracks on the upper flange of the rear flue sheet. There is no use to attempt to weld these cracks with all the flues and rivets in. To obtain a permanent job it is necessary to remove the rivets as far as the line of welding and cut out the defected portion. Flange out a new piece of boiler plate and set it in in a straight line, as per Figure 9. It is necessary that the flanging should be a little exaggerated, or in other words more than square. Then weld the straight line on the flue sheet and after it cools off replace rivets so as to join flue sheet to crown sheet. One will find that after the weld cools off that the flange will be separated a little from crown sheet, due to the contraction of the weld, but having, as mentioned above, the flanging exaggerated or more than square, one can heat the flange and make then a perfect fit before the riveting.

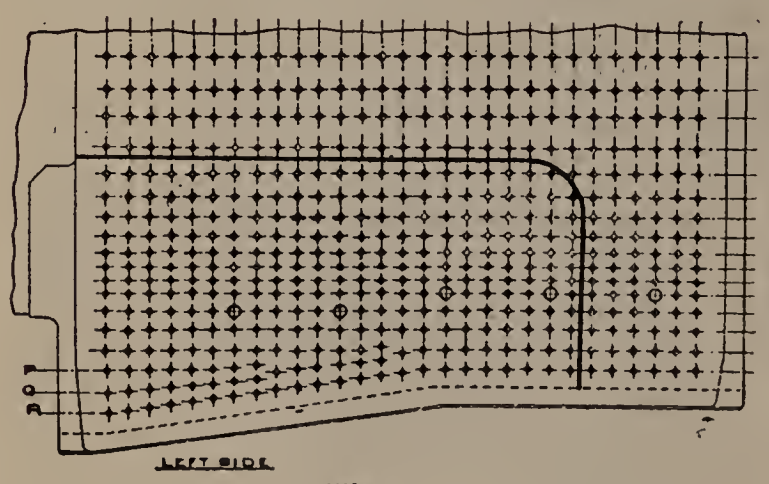


Fig. 13.

Figure 10 of a similar patch, but with curved ends, is not satisfactory because it sets up an undue strain on the vertical edges.

There are a great many cases where back head sheets, flue sheets, door sheets or throat sheets around the mud hole or mud ring, are badly corroded and need repairing. If the corroded area is not over four or five inches in diameter one can clean or remove the scale and build up enough metal until plate has reached its original thickness. If the rivets get loosened from the heat one can tighten the same mud ring rivets, because both ends of rivets can be reached with proper riveting tools.

When side sheets, flue or door sheets are getting mud burnt or blistered, or developing too many cracks they are removed and new ones welded in. In case of side sheets being set in for welding a straight line, as shown in Figure 11, is the best arrangement. Some boiler makers with the desire of saving boiler plate, are preparing side sheets as per Figures 12 and 13, but they are set up wrong and the whole job is jeopardized so as to save a piece of boiler plate.

It is advisable always to cut sheets a half inch longer, and when the welding is completed, the surplus material can be trimmed off at the same time when the caulking edge is made.

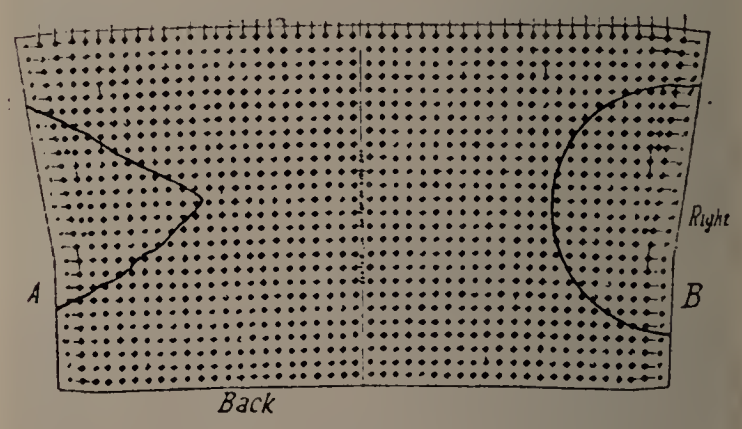


Fig. 14.

Sheets should be bolted and clamped so as to keep them in position during the welding operation. Drive in steel wedges between the bevelled edges about six inches apart. Commence welding at the center of seam and as the operator advances about six inches he will notice the edges will close a little, due to the expansion, regardless of the steel wedges, therefore, stop welding in that direction and begin on the opposite end. When, after six inches of welding, the operator will experience the same thing. However, by that time the first six inches of welding has cooled off some and contracted, or in other words, the edges have widened. Start to weld there again for another six or eight inches, never advancing too far, so as to allow the edges to close entirely or to overlap. Continue the welding operation in such alternate sections until the whole seam is welded.

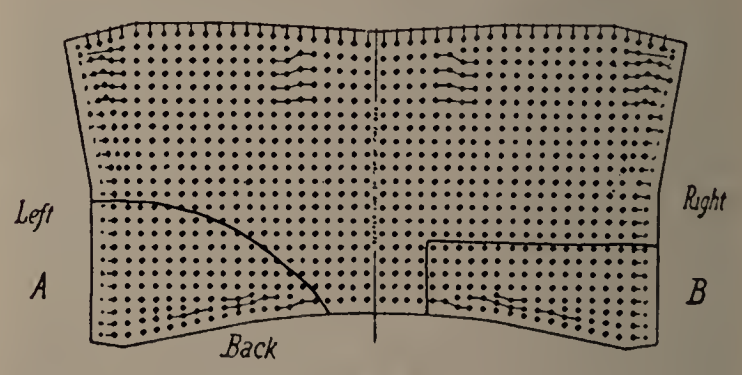


Fig. 15.

If the corrosion on some sheets is extending more liberal, or gets too deep in the sheet, it is desirable to cut the defective plate out, drive out the mud ring rivets and set a new patch in, as per Figure 14-B or Figure 15-A.

The patches with sharp corners, as shown in 14-A or 15-B are not satisfactory and it requires more lineal inches of welding.

Figures 7 and 8 show two such patches before and after welding.

Figure 16 shows the lower half section of a rear flue sheet that was welded in. When either half needs to be replaced the illustration shown is one of the best arrangements. In welding the lower half, it is well to make the horizontal weld first, then the flanged edges may be welded to

the side sheets. In welding the upper half of flue sheet, it is best to weld only the horizontal line and thus join both halves, but the flanged edges of the crown and side sheets should be riveted.

In welding a whole new flue sheet to side and crown sheets, it is necessary to set up flue sheet in place, fastened temporarily with bolts and clamps. The beveled edges must be separated with wedges about $\frac{3}{16}$ inch. Commence to weld the overhead line and, if possible, go in the boiler through the dome

In welding in a new door sheet, follow the same instructions as in welding a flue sheet, and when welding is completed and cooled off, one can finish welding the circumference around the fire door hole. This weld must always be done at the end of the welding operation, and the edge should butt weld to the back head sheet, as per Figure 19.

Figure 17 shows a new door sheet welded on to the crown sheet, side sheets and then around the fire door to the back head sheet.

Fig. 16.

and go over the same weld, and reinforce it $\frac{1}{16}$ inch from the inside; then weld one vertical side and then the other. The sheet not being fastened with the flues or rivets will expand freely towards the front end when heated and contract readily when cooled.

Overhead welding does not require any more skill than any other kind of welding. When one can make a good weld in a vertical or horizontal position he can surely go right ahead and weld overhead, provided he has the proper 45° head torch and a good regulator.

The only thing that stopped the author from overhead welding for a little while was imagination. When the latter is overcome a good welder will find it easier to weld overhead than horizontal.

In welding one or more cracks in flue sheets, or what we call bridges, it is best to remove the flue from the defective flue hole, also the two opposing flues. Bevel the crack, then heat the two opposite bridges that run parallel with the cracked bridge. In doing this the operator will separate the cracked edges, or in other words, cause expansion before welding. Then weld the bridge as speedily as possible. As a further precaution, some welders are heating the flue sheet flange at the curve on both sides, parallel with the weld. This heating is very recommendable and if followed by welders many a flue sheet will be saved.

Figure 16 shows a flue sheet composed of an old upper half and a new lower half welded all around the crown sheet and side sheets.

For the last few years the development of welding entire fire boxes has made slow progress, but it has come to stay. The superiority and low cost of this type of joint is unquestionable, and the field of this application of the process is growing steadily.

The first operation necessary is to cut all rivet heads from the mud ring and drive out the stubs. Then replace the same size bolts about every tenth hole at the mud ring. This is necessary so as to keep mud ring and the outside sheets properly lined up. Then cut out all stay bolts, beginning from the crown sheet down to the mud ring. Figure 18 shows a locomotive fire box with all sheets cut out with the Oxy-Acetylene process. The two upper side sheets were left in place because they were in good condition. The cutting operation was performed in the following order:

1—Two lower side sheets as per Figure 18.

2—Flue sheet as per Figure 18.

3—Door sheet as per Figure 18.

4—Crown sheet as per Figure 18.

5—Two corner patches on outside back sheet as per Figure 7.

6—Door collar on back head sheet as per Figure 7.

7—Stay bolt stubs as shown in Figure 18. right side.

The next operation was to cut flange and bevel the new sheets and then weld them in the following order:

1—Crown sheet welded to the two old side sheets as per Figures 16 and 17.

2—Lower side sheets welded to the upper ones as per Figures 16 and 17.

3—Upper old flue sheet welded to lower

half, crown and side sheets as per Figure 16.

4—Lower flue sheet welded to both side sheets as per Figure 16.

5—Door sheet welded to crown and side sheets as per Figure 17.

6—Door collar welded to the outside back sheet as per Figure 8.

7—Two patches welded at the mud ring corners to back head sheet as per Figure 8.

8—Circular joint at the fire door hole butt welded, thus joining the door sheet with the back head sheet as per Figure 8.

The welding of flues with the oxy-acetylene process is practical in smaller shops where there is no great number of them to be welded. However, one can reduce the cost to about 40 per cent if oil furnaces and special jigs are employed for this purpose.

In case the oxy-acetylene process is used, it is best to place the flue into an angle iron and weld it all around, taking care not to leave any lump on the inside. The in-

Fig. 17.

side surface of a flue must be clean so the flue cleaner can get through after that flue is in operation and needs cleaning. By using the right size tip and a ⅛ inch filler rod one can weld a hundred two inch flues in three hours and not leave one lump of metal in any of the flues.

When a set of locomotive flues has to be taken out and the front sheet is not to be removed there is a practice among boiler makers of reaming out one flue hole a little larger and through this hole the 365 or

Fig. 18.

more flues are taken out. I have seen times when a set of flues were so thickly coated with scale that it required many days and nights of hard labor to remove these flues through the enlarged flue hole. Even under favorable conditions this operation is regarded as the hardest job in boilermaking. However, it is suggested in such cases to cut a round hole in the center of the flue sheet.

Through such a hole all the flues are removed as fast as they can be handed out of the boiler, then the same piece that was cut out is beveled on both edges to a 45 degree angle and welded back in its place.

The welding of locomotive flues to the flue sheet with the oxy-acetylene process requires more care and is very expensive and for the present should be discouraged, especially when one has to weld the flues to an old sheet.

In this case the electric welding will be found more practical and less expensive. The flues are set in the same as usual and after the setting, rolling and beading are completed, it is necessary to clean off the surface free from all oily or greasy substances.

A sand blast is the best and quickest agent to clean the flue sheet. The metal electrode is used to weld the beaded portion of the flue to the sheet. This deposit of metal has no holding power and is intended only as a seal and a remedy against leaky flues, therefore, one should abstain from building on the sheet a great deal of metal. One good layer will serve its purpose.

If, in testing, any leaky blowholes should be found in the welded flues it is better to caulk the material than to add new metal. Sometimes one is confronted with a broken mud ring. These rings are generally made of cast steel—they can be welded similarly to the locomotive frame provided the ring is off, or it is not covered with the sheet at the fracture. In case the ring is in the fire box it is necessary to expand the ring about ¼ inch before welding. This can be done with a jack or by driving in a wedge. If the ring is out on the floor it is not necessary for the above precautions. If the welding is to be done in the fire box and the sheet is covered at one side, then make the bevel on one side. But if the ring is out on the floor the bevel should be cut on both sides, so two operators can make the weld at the same time.

If certain portions of mud ring are worn or corroded the electric arc can be employed to rebuild these spots at less cost than oxy-acetylene. However, if an electric welding machine is not available one can use the oxy-acetylene process at a little higher cost.

Rivets can be cut out in fire box with the oxy-acetylene process at a less cost than the mechanical process. If the head is flat on each side then concentrate the pre-heating flame on the center of rivet until the metal starts to fuse. Apply then the blower or high pressure valve and blow a hole through. By this time the whole rivet will become a dark red, while the sheet around

the rivet will remain black. This feature of difference in colors should help the operator to burn the rivet material only by moving the nozzle around the center until all the red hot metal is blown through the sheet. Thus a bare round hole is left on

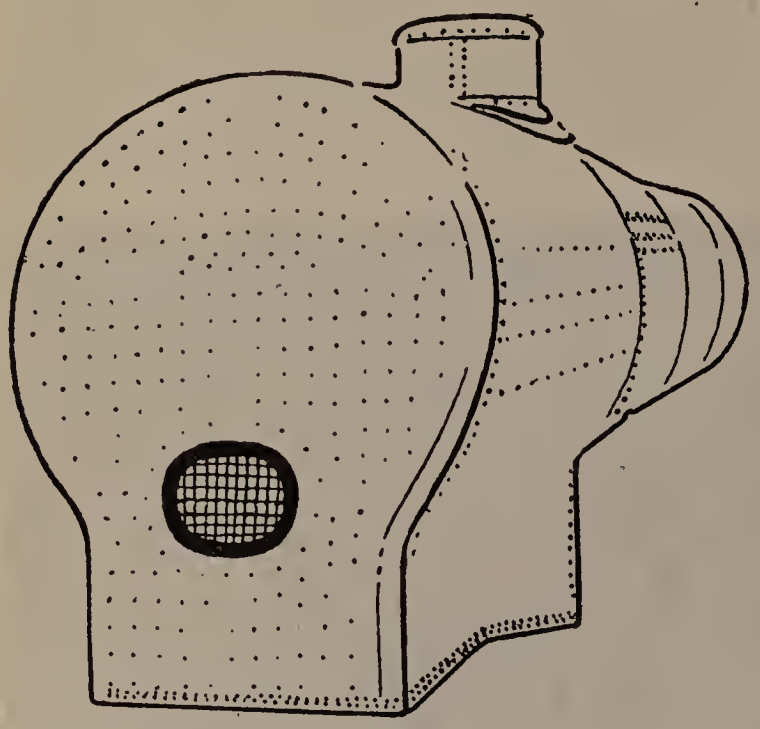


Fig. 19.

the sheet. If the heads are round, then cut off the heads first and follow the above method to cut the internal part of the rivet. Figure 20 shows method of holding the torch when starting to cut off rivet head.

Old stay bolts as shown in Figure 18,

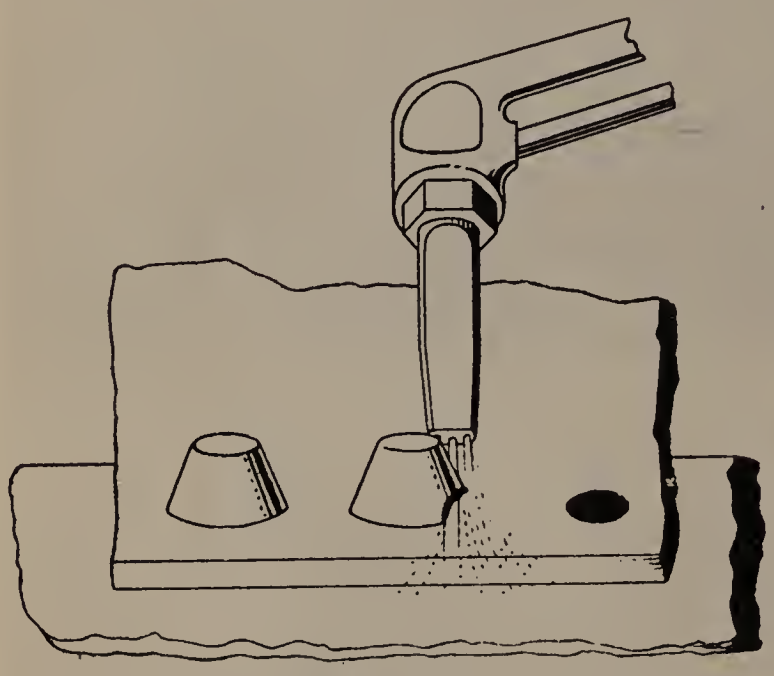


Fig. 20.

right side, can be cut with the oxy-acetylene process faster and cheaper than the mechanical process. Figure 21 illustrates in four numerical orders how to cut these stay bolts, and one will find this operation a great help in the boiler shop.

When old stay bolts are cut out, new ones must be put in later. These bolts are screwed in from either side and are generally left longer. These ends must be cut

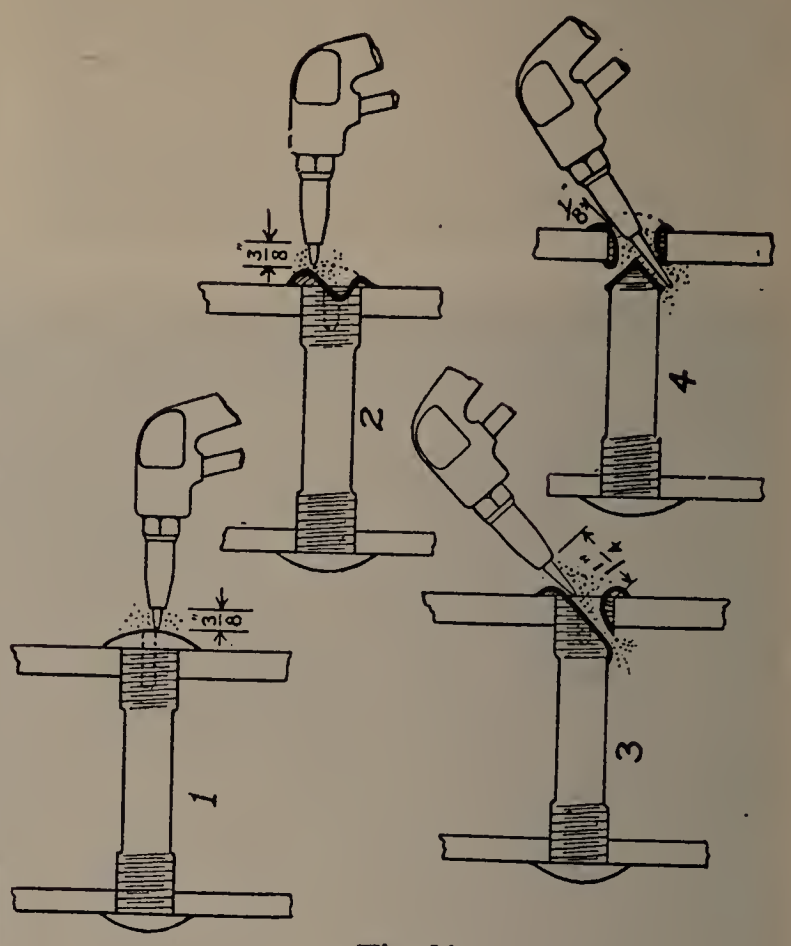


Fig. 21.

off to proper size, then riveted. It is cheaper to cut these ends with the oxy-acetylene process, furthermore the bolts are not loosened in the sheet, as occurs if they are

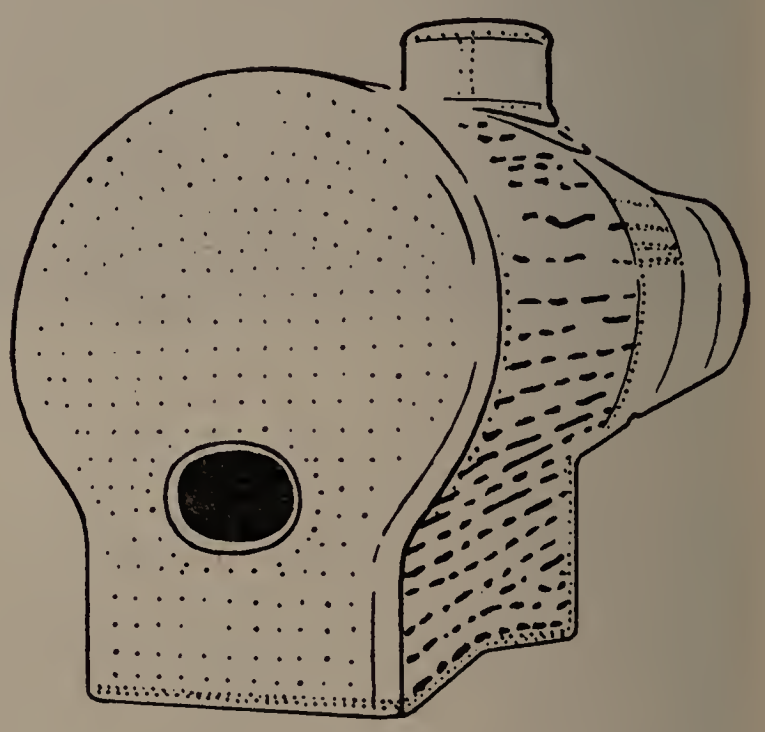


Fig. 22.

cut with a chisel or shears. Figure 22 illustrates a whole side of a fire box with the new stay bolts cut off with the oxy-acetylene process.

Boiler Welding With the Electric Arc

The following recommendations regarding the electric arc welding of boilers were made in a report prepared by the Electric Arc Welding committee of the Master Boiler Makers Association (1922).

Welding electrodes that have the approved chemical contents or elements which will give the best tensile strength which conditions may require should be adopted for boiler repairs. Another important point is that welding electrodes which are to be used on firebox welding should have even flowing qualities; that is, the globules of metal should flow from the point of the electrodes to the work in a steady stream, so they will not interfere with the skill of the operator or the functions of the electric arc. The efficiency of the operator should be fully determined before he is allowed to perform any welding in locomotive fireboxes, by having him weld specimens at least once each

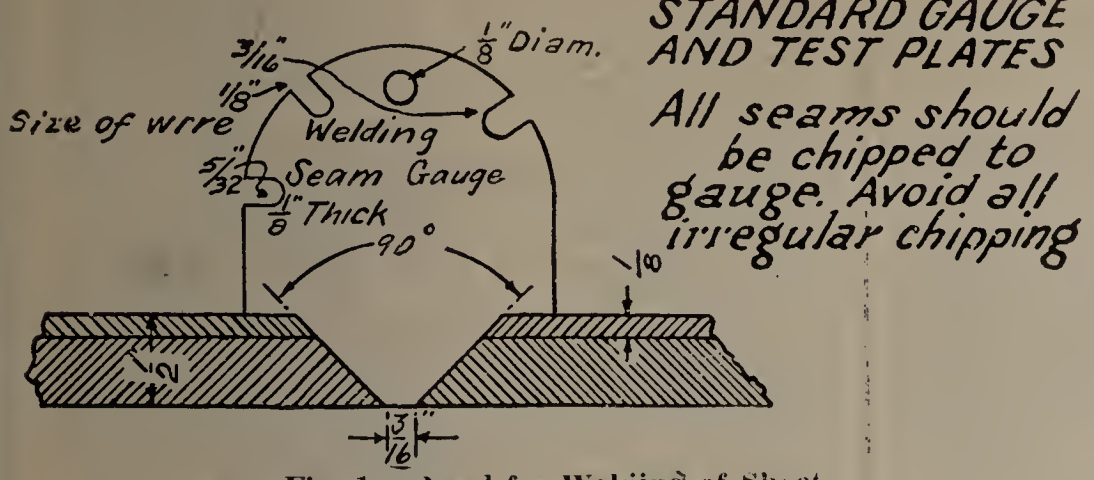


Fig. 1. Bevel for Welding of Sheet.

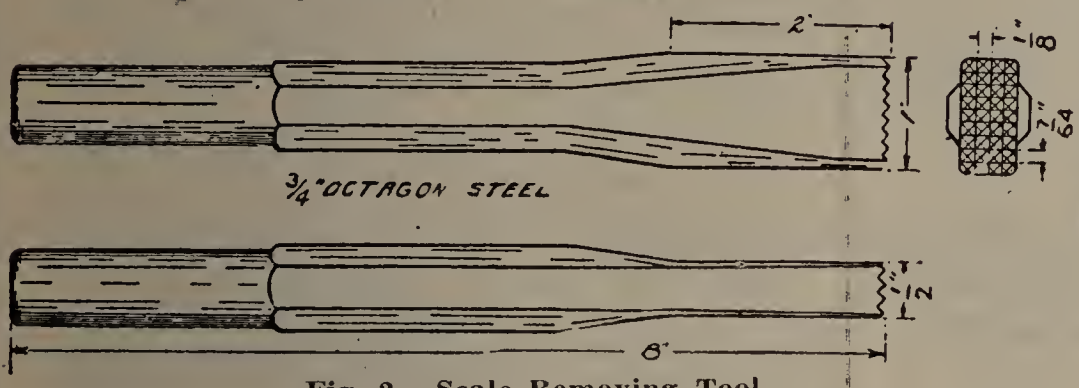


Fig. 2. Scale Removing Tool.

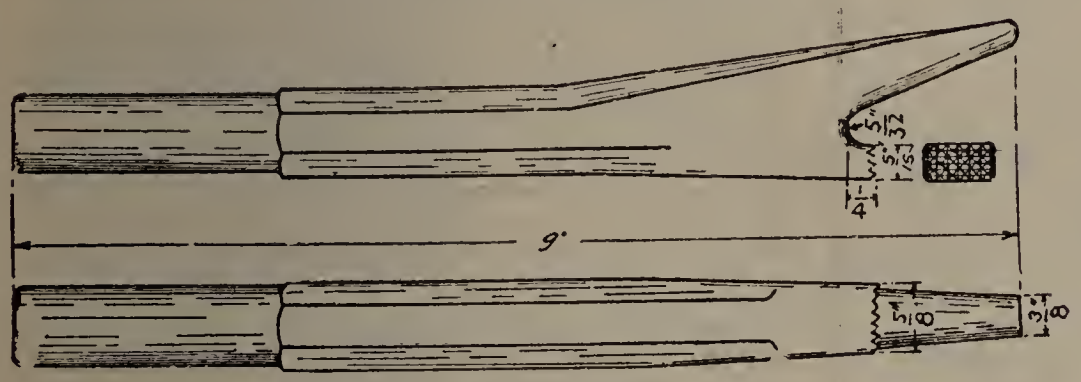


Fig. 3. Bead Scale Remover.

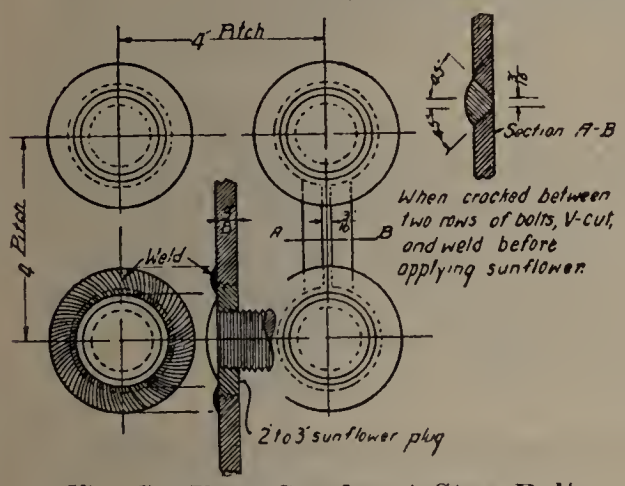


Fig. 7. How Cracks at Stay Bolt Holes Are Welded.

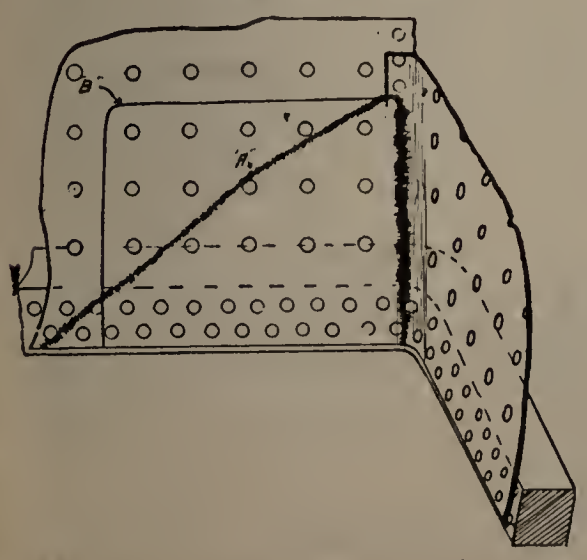


Fig. 10. Corner Patch in Side Sheets.

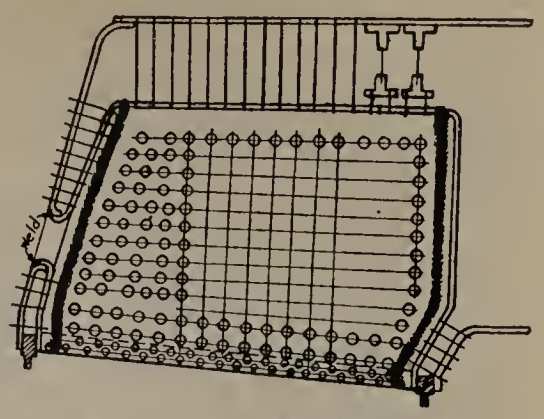


Fig. 4. How the Firebox is Welded

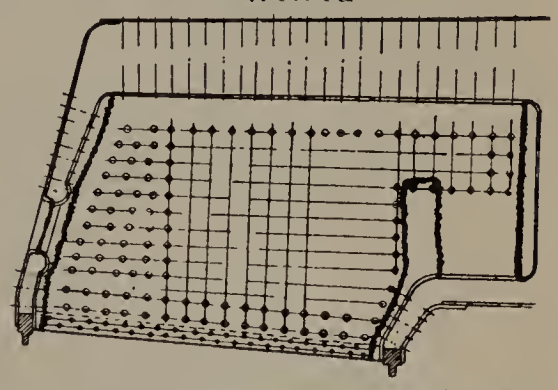


Fig. 5. Firebox and Combustion Chamber Welded.

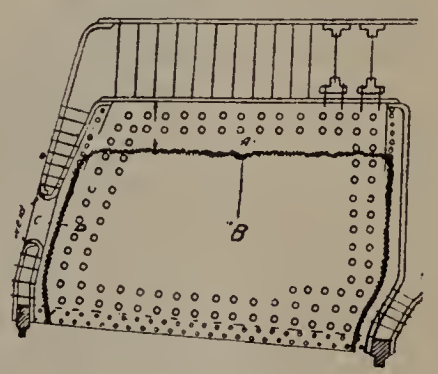
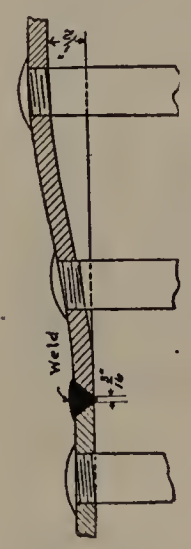


Fig. 6. The Knuckle-patch in the Firebox.



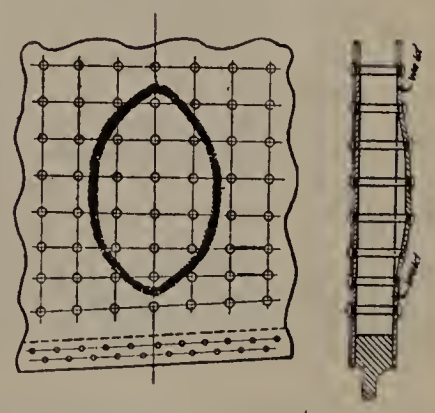
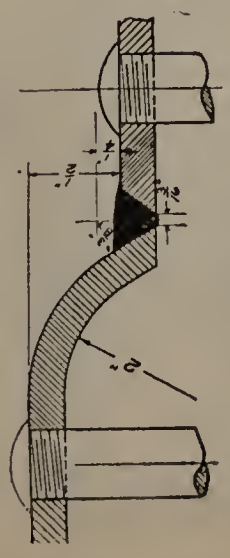


Fig. 8. Patching Around Defective Staybolts.



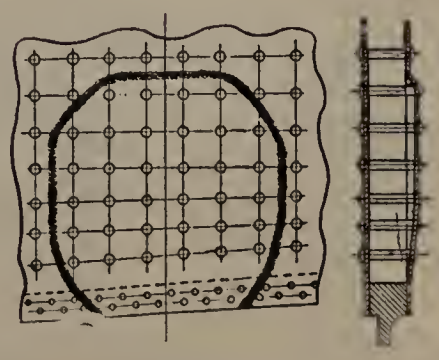


Fig. 9. Patch in Side Sheet.

month. The welded specimens should be forwarded to the engineer of tests who will test them for tensile strength. The efficiency of the welded specimen should be at least 75 percent of the firebox steel used, before the operator is allowed to do any firebox welding.

It is important that good judgment should be exercised in assigning operators to autogenous welding in fireboxes.

Another important feature is that no piece of work should be welded unless it is properly prepared. That is, all seams should be beveled as in Fig. 1, and should be thoroughly cleaned, free from grease, rust, scale and other foreign substances. It is very essential that the weld be made on bright clean metal and that this condition be preserved throughout the entire welding operation. The use of a roughing tool as shown in Figs. 2 and 3, or a sand-blast machine, may be used for cleaning purposes. All seams should be carefully fitted and beveled to 45 degrees, not allowing more than ¼-inch or less than $\frac{3}{16}$-inch space at the bottom of the V as shown in Fig. 1, as determined by the use of a gage.

If the opening at the bottom of the V closes to less than $\frac{3}{16}$-inch, the welder should stop and have it chipped to the standard opening. Under no condition should the plate be burned with the cutting torch to enlarge the opening, unless it is going to be chipped afterward.

Welding of Complete Fireboxes.

All sheets should be beveled on the rivet line from the fire side, Fig. 4, and plates should be fitted into the mud ring, held together with strongbacks or clamps about every 12 inches in order to hold the plates in perfect line. The sheet should then be tack welded between each of the clamps, the tacks being from two to three inches wide. After this operation has been performed, the clamps should be removed and the intermediate spaces welded. Do not remove the firebox from the ring until after the welding has been completed. All seams should be reinforced 20 percent of the thickness of the firebox sheet on the fire side and when it is possible to do so, seams should be reinforced on the water side approximately 10 percent, especially on the crown sheet.

All welding should be started at the bottom of each intermediate space and finished at the top of the seam. For all firebox work current values from 100 to 125 amperes will give the best results when properly handled by the operator using a $\frac{5}{32}$-inch diameter electrode. The cost of welding firebox seams per lineal foot is 90 cents for labor, material and current.

Preparing Half Side and Door Sheet for Welding

The sheet should be bolted to the mud ring after it has been properly beveled and fitted in place. Stay bolts may be applied, except the rows adjacent to the seam which is to be welded. All horizontal seams should be held in place with strut bolts and tack welded every 12 or 14 inches. Then weld intermediate spaces alternating from the center space to the spaces at either end. Vertical seams should be tack welded similar to horizontal seams. After being tacked, start welding at the bottom space and finish at the top space. Current values for successful welding on this operation are the same as for firebox welding described in Fig. 4 and Fig. 5.

Firebox Sheet Knuckle Patch

Preparation for the firebox knuckle patch, Fig. 6, may be followed as outlined for the welding of half side sheets or door sheets. The use of strut bolts can be applied to hold the patch in line when necessary, while it is being tack welded. All strut bolts should be removed after the patch is welded into position. Under no circumstances should the knuckle patch be less than 12 inches from the crown sheet.

Weld the horizontal seam first, then tack weld the flanged sheet to the wrapper sheet. Remove all strut bolts and weld intermediate spaces, working from the bottom on either side of the patch upward, finishing at the top.

The method indicated in Fig. 7 is to be used to repair cracks at staybolt holes in firebox sheets, where not more than 6 sunflowers are necessary to complete repairs, and not more than 4 sunflowers will be joined together. This system may be used in main shop general repair, sunflowers not to exceed 3 inches in diameter.

Repairing Small Portions of Side Sheet

When the defective portion does not extend over six staybolts repairs can be made as per instructions given for Fig. 7, which give very efficient results. When the defective portion is larger it is then advisable to use methods as shown in Fig. 8, by removing the defective portion and applying a patch of an elliptical or circular shape. In preparing the patch, sufficient metal should be allowed so that when the patch is dished ⅜ to ½-inch in the center, the opening at the seam should not be more than ¼-inch wide at the bottom of the V and not less than $\frac{3}{16}$-inch. The patch should be held in place by strut bolts and tack welded on the right or left side; then weld this seam of the patch before the opposite side is tack welded, so as to allow the patch to draw in one direction. After this has been completed, allow it to cool before starting on the opposite side. By so doing there will be only one contraction of the patch. All welding should be performed from the bottom upward. Should the defective portion of the side sheet extend down to the mud ring rivets, apply the patch as in Fig. 9, the welding operation being the same as outlined for Fig. 8. Should the defective portion be at a location as shown in Fig. 10, the seam may be applied as indicated by line "A."

Should the plate at the corner of a firebox become defective and it is necessary to remove a portion of the side sheet and the door sheet, it is advisable to apply a patch to both sheets as in Fig. 11.

Should it be necessary to make repairs according to Fig. 12, Fig. 13 and Fig. 14, the work should be done by welding from the fire side of the sheets and reinforcing them on the water side.

Method of Welding Patch on Front of Crown Sheet

Should it be necessary to repair the front portion of the crown sheet, prepare for welding as outlined previously. A very important feature about this welded seam is that the front point adjacent to the flue sheet should be finished on the flat side of the firebox at least 12 to 14 inches below the highest point of the crown sheet.

Welding of Seams

Should the seams become defective and cause considerable trouble, repairs can be made with the electric arc process as shown in Figs. 15 and 16.

Remove the defective portion of the flange, which is giving trouble, by cutting through the back of the rivet holes, bevel the sheet 45 degrees and tack weld it every 12 inches; then weld the intermediate spaces. The weld should not be any thicker than the flange of the sheet and tapered to

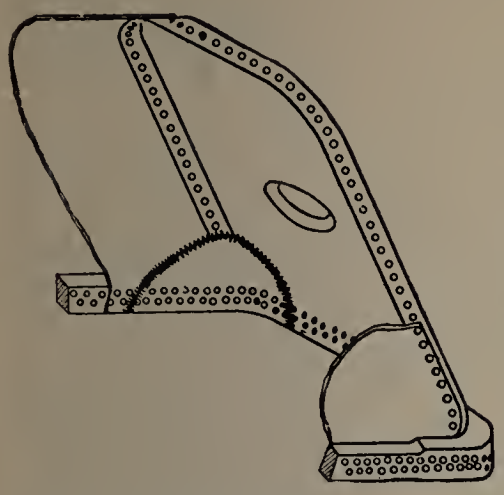


Fig. 11. Patch at Junction of Side and Door Sheet.

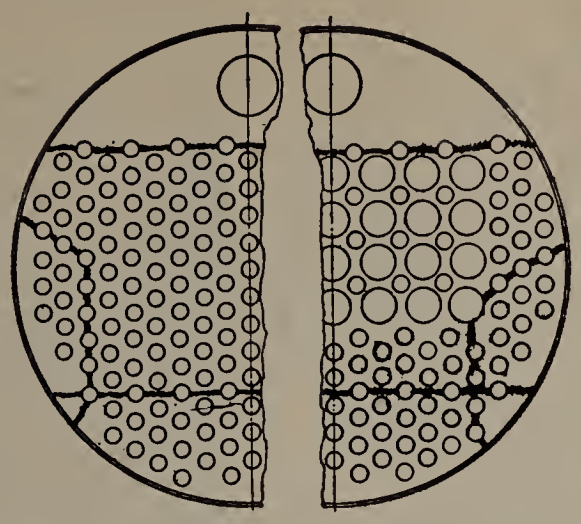


Fig. 12. Patches Welded in Front and Back Flue Sheets.

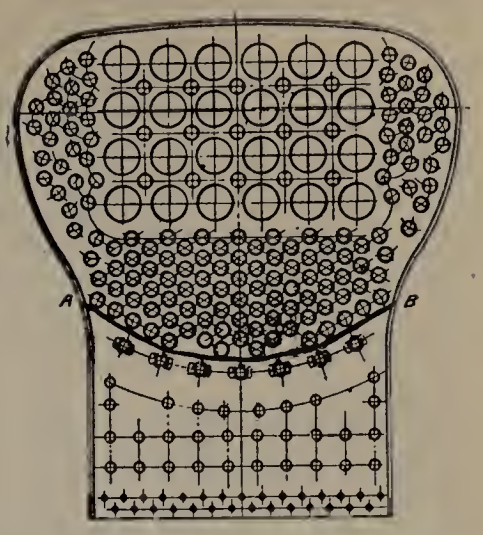


Fig. 13. Top Portion of Back Flue Sheet as Arranged New for Superheater.

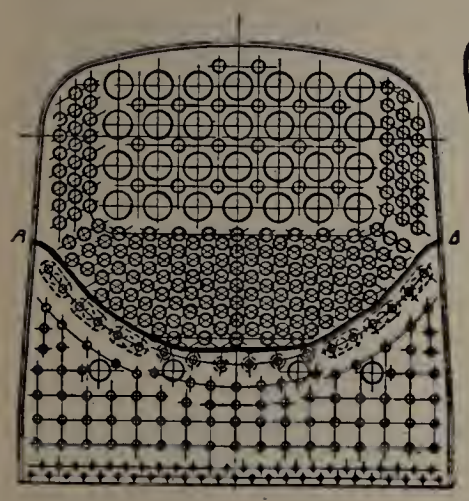


Fig. 14. New Top Portion With Wide Firebox, Back Flue Sheet.

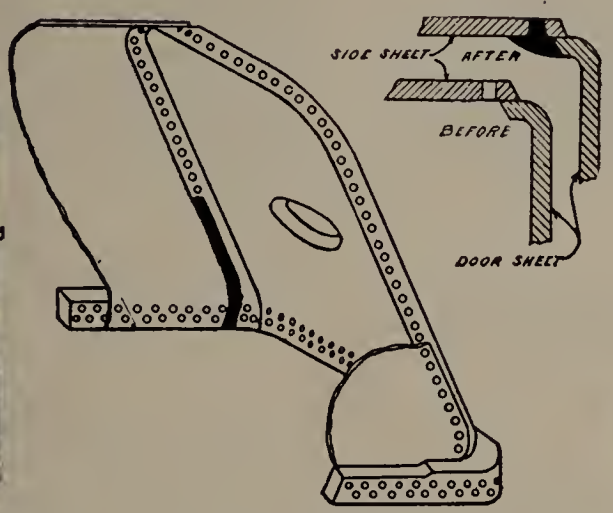


Fig. 15. Method of Welding Defective Seams.

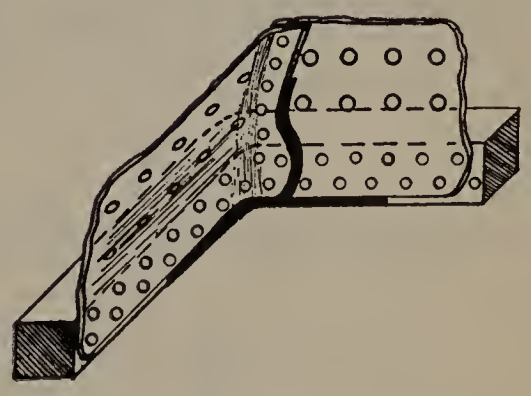


Fig. 16. Repair to a Leaky Mud Ring Corner.

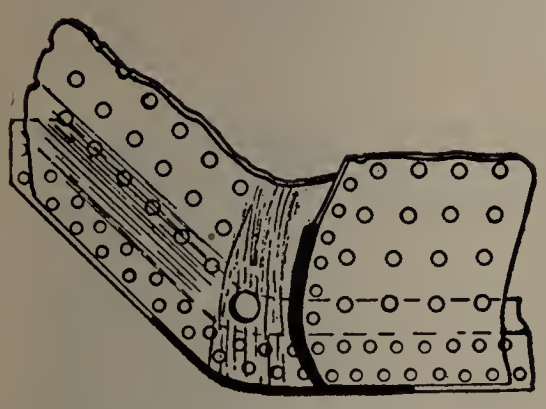


Fig. 16A. Another Section of the Mud Ring.

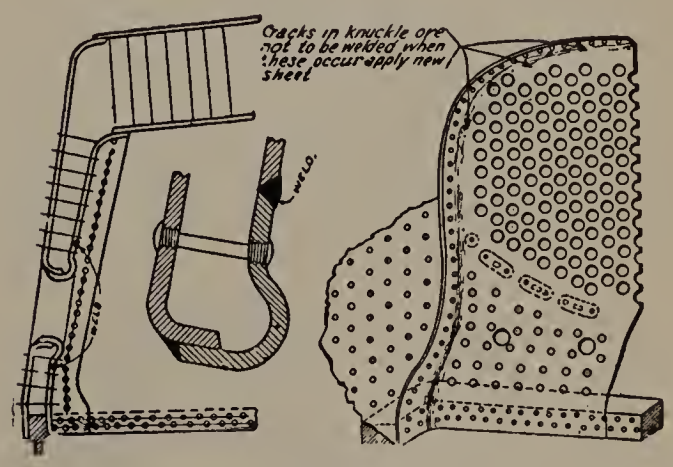


Fig. 18. Knuckle Cracks Not to Be Welded.

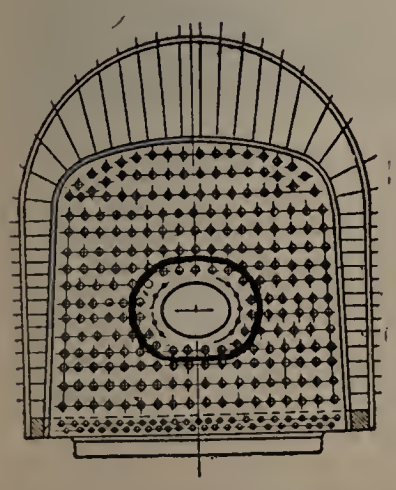


Fig. 17. Patch Welded on Door Collar.

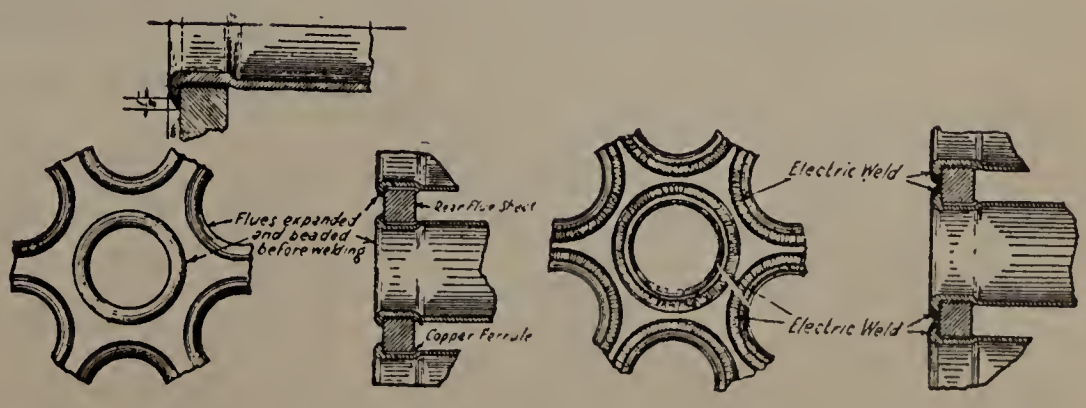


Fig. 19. Use This Method of Applying Flues in Locomotive Boilers by Means of the Electric Arc Welding Process.

a point. Weld the old rivet hole solid as shown in the illustration.

Broken Mud Ring

In case mud rings become broken it is advisable to remove a portion of the firebox sheet. Bevel the mud ring from the top, giving at least ¼-inch opening at the bottom of the V, and reinforce it at the bottom of the mud ring after the weld has been completed on the top portion, afterward applying a patch on the portion of the firebox which was removed. The welding current values for welding mud rings are from 125 to 150 amperes, using an electrode $\frac{5}{32}$-inch in diameter.

Should the door collar become defective, the defective portion can be removed and a patch applied as in Fig. 17, following the instructions as described for Fig. 8.

Improper Welding of Firebox Plates

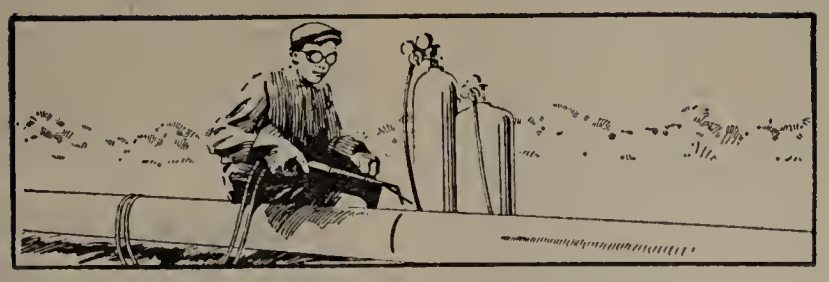
Under no circumstances should welding be allowed directly in the knuckles of firebox sheets as shown on Fig. 18. This ruling should be enforced vigorously.

It is very important when applying copper flue ferrules to the flue sheet that, when set and rolled. they do not project out on the fire side of the sheet, so that when the flue is applied the copper will not project under the flue beads. After the flues have been set in the regular manner very good results may be obtained by welding them after having received the second working. That is, if the locomotive is allowed to work its regular turn until the flues are to be reworked the second time, this allows the flues and flue sheets to get a good setting. By so doing it also allows the grease to be burned off the sheet.

After the flues are worked the second time, the sheets should be thoroughly sand blasted. When welding, the top row of flues should be welded first, the second row next and so on until the entire flue sheet has all the flues welded to it. It is very essential that the welding should be started at the bottom of the flue and worked upward, the weld being finished at the top of the flue to secure satisfactory results. It is in this operation that the flowing quality of the electrode is most important and should be given a great deal of consideration. The heat values on this operation vary widely and the operators should use their best judgment according to conditions.

Care should also be exercised on the part of the operator not to apply an excessive amount of metal. If he should do so, the metal will overheat and crack and cause a great deal of trouble. If it should become necessary to reweld a leaky flue which has been welded previously, all the old metal or weld should be removed and the flue worked tight into the sheet, after which it should be sand blasted and welded as formerly described.

Pipe Welding



COMMON application of pipe welding is to be found in the welding of gas transmission lines, water pipe lines, refrigerating machinery, oil transmission lines, gas pressure lines, steam power lines, boiler tubes, compressed air lines, and condenser coils.

Advantages of Welded Pipe Joints

Welded joints do not require the use of heavy, expensive fittings, which have to be made to order for other types of joints. Welded joints are more serviceable and have longer life. They are cheaper to install than threaded joints, and once installed do

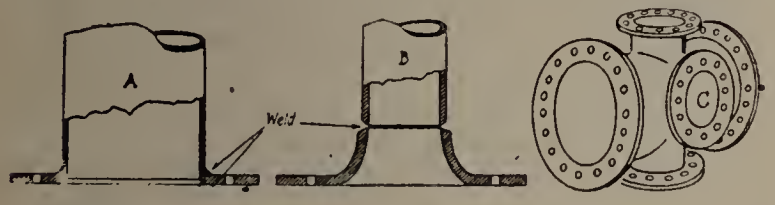


Fig. 1—Designs for Tee Connections

not have to be renewed so often. Since the weld makes one solid, homogeneous piece of metal from two pieces there is a minimum possibility of leaks developing. Very often a welded line can be constructed in less time than a threaded line. Testing of joints during and after construction is possible, since in the case of long pipe lines long sections can be made up and tested and then welded into the main line. Whenever special fittings are needed they can be made on the spot by welding, and then welded into place. (Fig. 1.)

Fig. 2—Example of Heavy Pipe Welding

PIPE WELDING PROCEDURE

There are several operations in pipe welding for which there should be specially designed machines. In acetylene cutting, for example, a machine operated torch can be used much more economically than the hand cutting torch because of its greater speed, both actually and compared to the volume of gases consumed. The machine operated torch also admits of far greater accuracy, thus reducing setting-up operations to a minimum and contributing to faster and better welding. The development of special machines should receive the united attention of oxy-acetylene welding instrument designers, machine builders, engineers and pipe fabricators, for the purpose of bringing forth new and better mechanisms and appliances as rapidly as possible.

We will now take up a comparison of a plain butt weld and a regularly flanged joint.

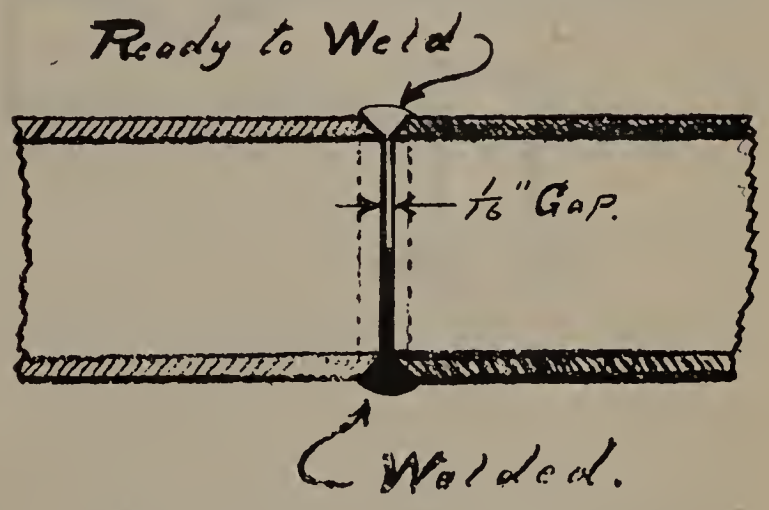


Fig. 3—Plain Butt Weld on Pipe Line

(See Fig. 3). The flanges may be counterbored and peened; they may be rolled or expanded type, plain like a boiler tube or with grooves turned in the flanges; they may be threaded only or threaded and peened, or of various other types, any of which forms can use rolled steel or cast iron flanges on steel pipe, but a lot of bolts and a gasket are required to complete what when finished can only be a temporary splice, as everyone knows of the expense and exasperation of maintaining gasket joints. The welded joint, when properly

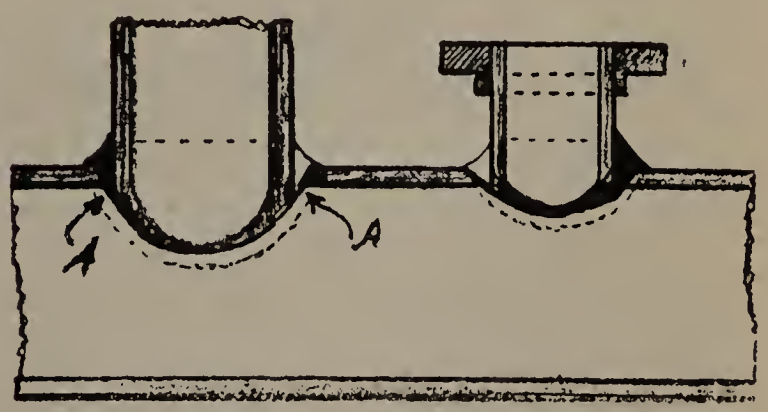


Fig. 4—Design for Welding Branch Lines

made, is neat appearing, is as durable as the pipe itself, does not interfere with hot or cold insulation and will not require any attention during the entire life of the pipe line, as a good weld does not deteriorate any faster than the parent metal. To make such a weld properly the ends of the pipe should be chamfered at an angle of 45 degrees and be placed in line with the tips not less than one-sixteenth of an inch apart in order that thorough penetration may be had to the inside of the pipe, which must be religiously done in all cases if the 100 per cent mark

of strength efficiency is expected. The welding rod or wire should be of as near the same carbon content as material in pipe as can ordinarily be had. Much depends on the welder, as no carelessness or guessing must be done in regulating flame of torch. The weld should be built up as rapidly as the molten metal can be handled without overlapping and in a continuous operation all around the pipe. If the welding flame is slowly moved over the first part welded for a few inches, the weld is automatically and homogeneously annealed for all practical purposes.

After completion of weld a hydrostatic test should be applied to at least double the working pressure to be carried. While the

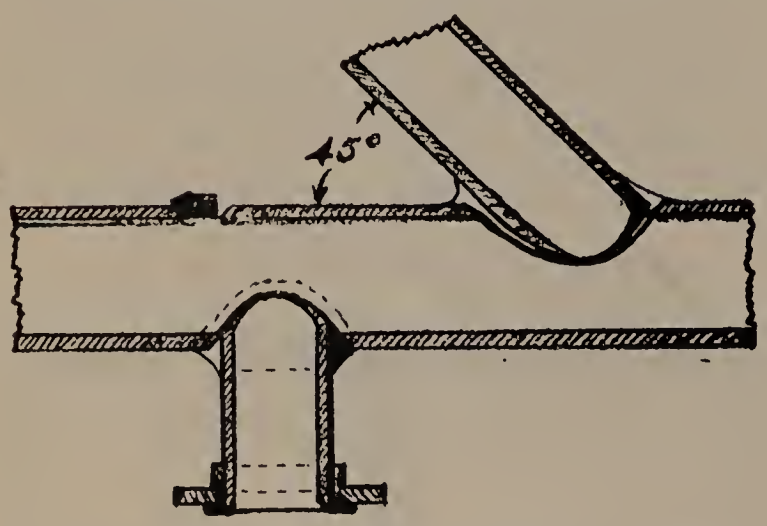


Fig. 5—A Smaller Branch Requires Shorter Ends on the Neck

pressure is on an impact and vibration test should be added by free use of a medium hand hammer in striking sharp blows all around the pipe on each side of, close to but not on the weld. That will show up porosity or cold shorts, by removing the small particles of oxide which in many cases temporarily prevent leaks from showing up during tests in which vibration is not applied. The idea of not hammering directly on the weld is that in doing so it sometimes happens that a thin shell is forged over small leaks which will soon corrode away.

A comparison of a welded neck or branch line, as from a header, and a regularly flanged tee with its gasket joints is not necessary, as any one can readily see. Regarding the welded neck or branch line (See Fig. 4) the operation requires a male and female cut, both of which should be machine made when a machine can be built. The hole should be cut at a good wide angle in order to form a good groove for the weld. The neck or branch must be cut so that it will conform to the inner contour of the main or header. The end of the neck or branch line will not require any bevel or chamfer at its short points, as there it goes through the other pipe, but at its long points it must meet the inner and outer face of main, therefore will have to be chamfered fully at those points, gradually lessening towards the short points. This would not be the case if the neck or branch is of smaller diameter than the main or header, as can be noted by reference to Fig. 4 or Fig. 5, the smaller the branch compared with the main the shorter will be the ends on the neck and less bevel at the long points.

Note that the hole must be cut so that when set up ready to weld there is the required one-sixteenth inch clearance at all points, points AA included. In welding it is, of course impossible to make a thorough amalgamation with all of the fibre layers or courses of the neck or branch at points AA. Extra strength must be added by building up the weld to form a good fillet to a radius of about twice the thickness of the pipe. This article has been referring to a 90 degree branch, but, except for the shape of cuts, it all applies to any angle branch line or neck. A neck should never be welded on and then have center cut out afterwards unless it is short and of not less than 14 inches diameter, so that the end can be welded over after the cutting has been done; otherwise the weld will be a poor one and have a low efficiency. The testing of such welds, or in fact any pipe welds, should be as described for plain butt welds.

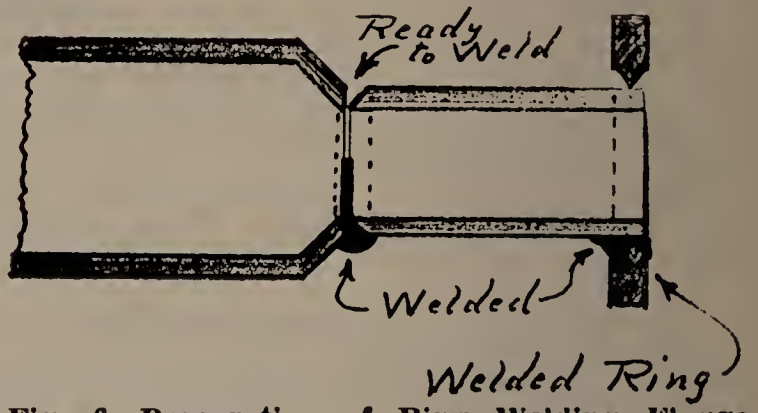


Fig. 6—Preparation of Ring Welding Flange

Very frequently flanges should be and are welded on necks, branch lines and main lines and headers. Sometimes screwed flanges are used and simply welded on the back as a sure seal, but usually they are of the rolled steel hub, or ring types (See Fig. 6). The sketch shows a ring welding flange which is prepared by boring to exact size of outside of pipe and then chamfering each

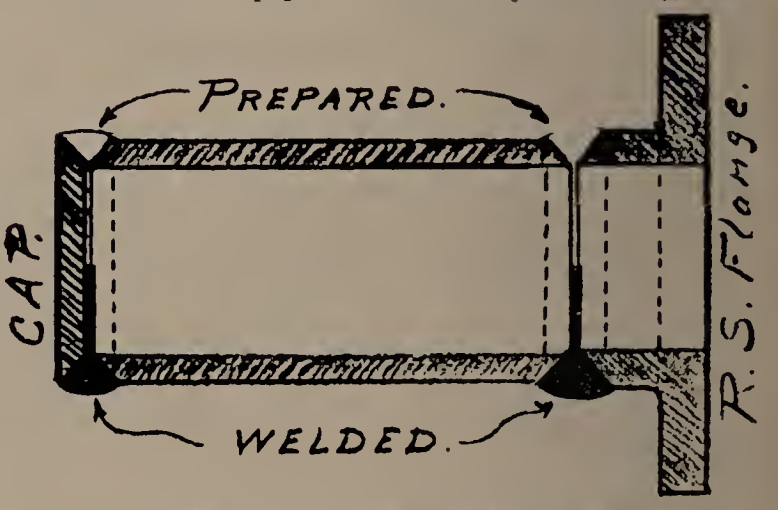


Fig. 7—Hub Welding Flange

side to a 45 degree angle to center. They are welded with a small fillet on the pipe side and straight on the face side, allowance being made to reface the entire flange after welding and before testing.

Hub welding flanges (See Fig. 7) simply have a hub forged to practically same inner

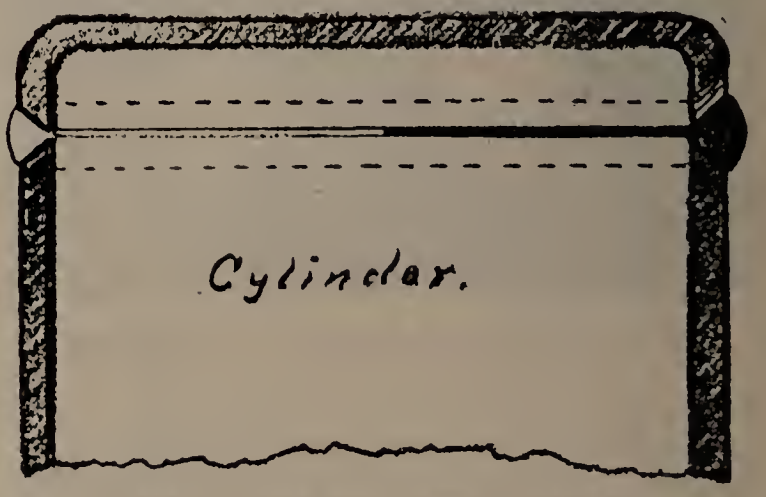


Fig. 8—Cylinder Head, Flanged

and outer diameters of the pipe; the end of the hubs are chamfered, thus the weld becomes a regular plain butt weld and is treated the same in every way.

Quite often the end of a pipe is to be closed with a welded plug or cap, as it

might be called. (See Fig. 7.) The picture shows the best form of getting the most strength at reasonable cost in sizes up to 6 or 7 inches, provided, of course, the pressure to be carried is not too high, in which case it would be necessary to dish the cap. In some cases it is found better to make the cap flanges as shown for Cylinder Head in Fig. 8. The size of the pipe and the pressure to be carried have to be the governing factors in deciding the

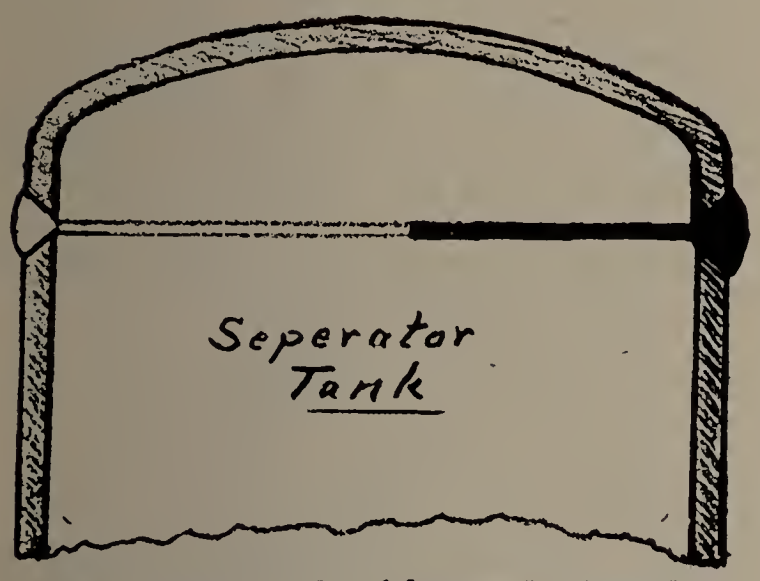


Fig 9—Cap Both Dished and Flanged

best and most suitable form for this work, as some cases require a cap or plug to be both dished and flanged, as shown in Fig. 9.

A welded separator or receiver head is by far the most serviceable when done as illustrated in Fig. 9. Steam separators are subject to sudden and frequent changes of temperature, causing terrific strains and stresses, with the result that riveted and caulked heads soon get to leaking in the joints and around rivets.

Air Condenser Pressure Stills

The strides that are being made in the use of oxy-acetylene welding for the fabrication of the more or less intricate equipment now being specially constructed to design and specification for oil refineries, are conspicuous. Work that was once done almost entirely by the use of threaded connections is yielding more and more to the oil-tight and gas-tight welded joint, not alone because of the demonstrated superiority of welding in this particular respect, but also because piping of the same weight is materially stronger when properly welded than when threads have to be cut for the screwed joints. An interesting example of the application of gas welding in this field is afforded in the welding of air condenser pressure stills.

The pictures give an excellent idea of the mechanism of the stills, showing the complete unit assembled, and top and bottom manifolds and one of the nine "harps" of which the unit consists. Every part, including flanges, couplings, headers and reinforcements, is welded.

Every unit in the assembly presents a special problem. Each neck on the welded headers has to be centered accurately, only a small tolerance being permitted, as the harps have to be so joined as to give absolutely tight and leak-proof connections and conform strictly to specification and design.

All flanged joints are made by the square lap method and all of the joints are welded. Reinforcing ribs are provided for the longer necks and connections of the welded header to give the structure an added factor of strength. On completing each unit thorough testing and rigid inspection are employed before approval for shipment. The work throughout is of a very high order and represents an interesting engineering development of the day.

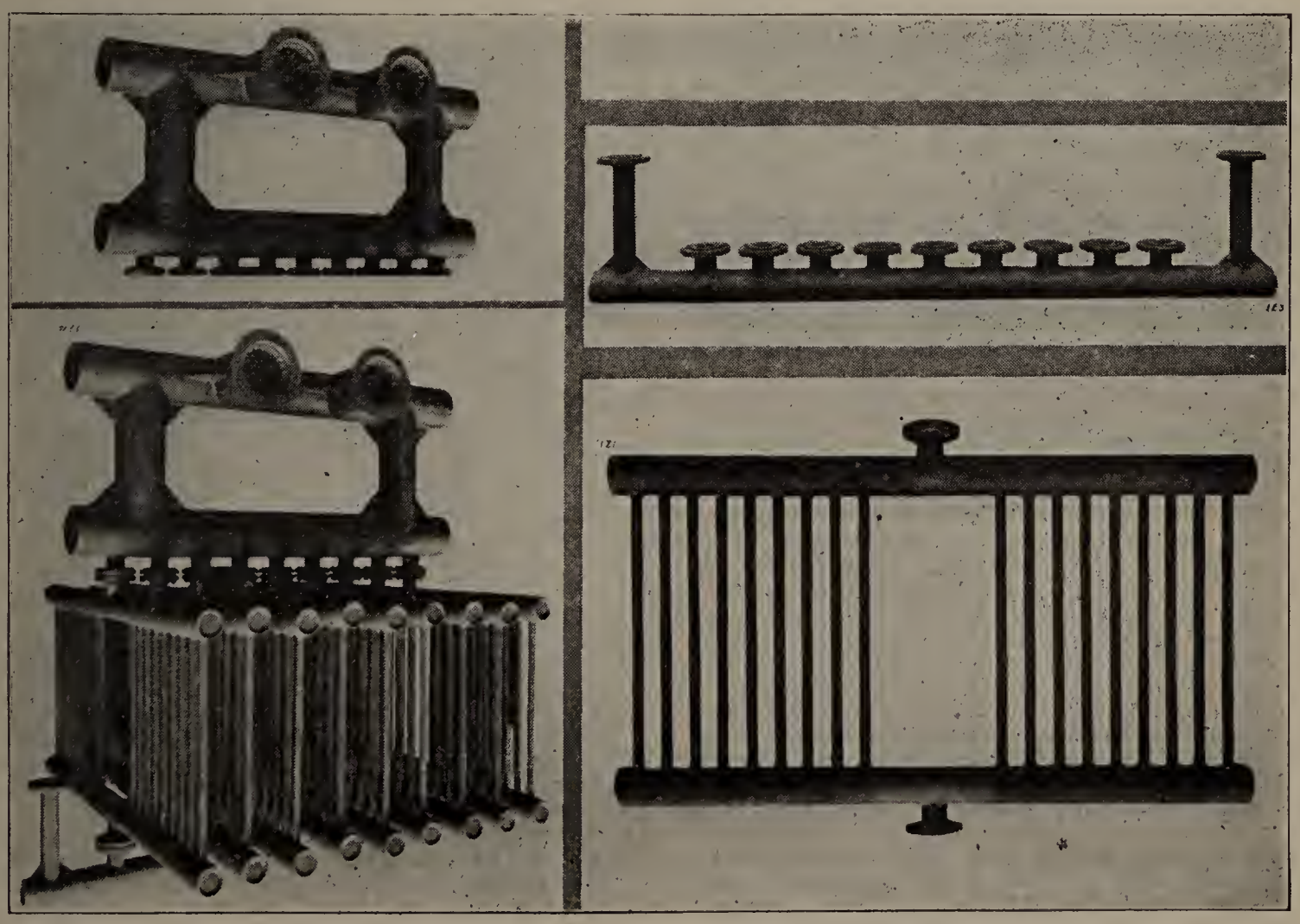


Fig. 10—Air Condenser Pressure Stills, All Welded

Gas Pressure Pipes

An all welded pipe line 890 feet in length and capable of withstanding a working pressure of 300 lbs. was constructed in

Portland, Oregon. The straight lengths were built in sections of 20 ft. with a diameter of 32 and 30 inches. Each section was composed of four separate cans, five feet long. Girth seams and straight seams were all butted together, leaving a sixteenth opening to prevent overlapping. All seams were beveled to a 45° angle with the bevel on the inside of the straight seaming. The cans were rolled from 5/16, 3/8 and 7/16 Ingot steel and tacked together with a 5/16, 3/8 and 7/16 butt strap on the out side of straight seams, thus making approximately 15 feet of straight seaming to be welded on each separate can. A double bead was used on the 3/8 and 7/16 inside seams with 5/32 and 3/16 electrodes. Taking the inside seam first, it was started in the center and welded toward each end, or as the operators preferred, starting about one-third of the way in, welded to the end, then back another one-third and up to the already welded portion, etc. Thus the operator did not have to crawl over hot metal, and also avoided having the tacking break. The welds are all made a trifle over flush which has a very dressy appearance. The object of the first bead is to weld all the way through, also to prevent the metal from being porous, if a single bead were made. This allowed the second to be thoroughly fused with a close arc.

Each can, after being welded was assembled into sections (20 ft.), tacked and ready for welding. Steel ring expanders were placed on the inside of each girth seam to keep the pipe in shape, also acting as a backing for the weld. Here too the double weld was used, starting at any point and going right around, keeping about six inches ahead with the bottom bead. The two end seams were laced across, the outside with 8—3x2x3/8 straps, welded on over top, while the center girth seam had ten straps, all proportioned evenly around. These straps were put on just as soon as the operator passed the point which he considered the right place for it, then going on as before. In this way the strap cooled as the seam cooled leaving no chance for any unnecessary strains. Each welder was instructed not to start any girth seams unless he had time to go all the way around, because it was found that if he did not finish a complete seam, leaving it stand over night, there would something be sure to crack when he started in again on the cold pipe, the next day. Outside welding of girth seams and pads averaged sixteen feet to a seam.

After the sections were all welded on the outside, the expanders were taken out and a wash weld put on the inside, making about twenty-six feet on the inside to a section. Totaling up all the footage to a section, these were nearly 135 feet on the straight pipe.

The curves along the pipe were different angles and lengths. All of these were laid out and welded together, with angle iron straps around for anchoring to concrete foundations. Angles were welded both inside and out also using the small straps spaced evenly around. In many cases where the seam was quite wide a lace bead was used but on the inside it was kept as smooth as possible. The pipe line was provided with two reducing elbows branching from the main pipe by an all welded Y. This Y was of 7/16 metal, welded with double beading both inside and out and was reinforced in the crotch with a heavy six inch strap.

The scale of footage required was 5½ feet per hour on 7/16, 6½ on 3/8 and 7½ feet on 5/16 metals; but when working on straight seams the average was much better than that; and went as high as 12 feet an hour on 5/16 metal, depositing at that rate 2½ pounds of 3/16 welding wire. On the girth seams it took from 2½ to 3 hours to do one seam on 7/16 metal and even the lighter metals took nearly as long. Considerable time was lost in moving around, rolling pipe, and spacing the pads. The inside wash weld took about 2½ or more hours to a section. Thus it required over twenty hours to fully complete welding a twenty foot section of pipe.

Gas Transmission Lines

A good example of organization on pipe line work is found in a 10-inch gas trunk line in the Bakersfield territory in California. The welded portion of the line, some 18½ miles, is of especial interest because of certain features of construction and handling employed to meet unusual conditions of terrain and climate. The line is practically a cross-country straight away, with very few bends, traversing open prairie and marsh lands at points miles away from even the crudest pretense of a highway. The temperature variations are always considerable during the day, ranging from sharp chill in the morning and evening to scorching heat at midday, modified at times by stiff winds that rise almost to the velocity of gales. It is obvious that the welders had to contend not only with the ordinary difficulties of contraction and expansion, but with operating obstacles of an unusual nature.

Eleven welding crews, composed of welder and helper, were stationed at successive stages of the work at such intervals that it was necessary to move camp but three times to complete the line. Oxygen and acetylene tanks were moved from one point to the next on improvised sledges drawn by mules. The pipe and other material were shipped to the nearest railroad point and trucked from there to the work; horses being used whenever marsh lands had to be crossed.

The pipe, 10 inches inside diameter, weighing 27.37 pounds per linear foot, the sections averaging 35 feet in length, was delivered already beveled to 45 degrees at the ends, the bevels carrying through to the base or inside circumference of the tube. The ditch for the pipe was dug under contract with a machine ditcher, and was two feet in width and three feet deep.

Twenty lengths of pipe were assigned as to the operating unit for each welding crew. The pipe was laid on the side of the ditch and rested on skids, the crews welding the joints successively, rolling the pipe into place and turning it as the work progressed to keep the work horizontal. When a series of twenty sections was welded, the completed work was rolled on the skids until directly over the trench and lined up with the preceding series by means of chains and tongs. If it was found the two 20-section lengths overlapped, the overlap was cut away and the abutting ends welded. In cases where there was a gap instead of an overlap, the space was filled by welding in a short section of the right length.

During the actual welding, expansion and contraction of the pipe, due to atmospheric changes, were ignored, excepting when tying in the 20-length sections. The welding of the latter was always done in the cool of the morning to avoid any possibility of contractional ruptures. This was necessary, because, while expansion would take care of itself in effecting slight undulations in the line, without this provision for uptake, contraction tension might result in a break where, as in this case, the extreme variations in section lengths at different hours of the day sometimes amounted to as much as six or eight inches. For this reason also the pipe was lowered into the ditch only at the coldest periods of the day.

After three or four miles of pipe had been welded, painted and lowered in the ditch, a temporary tie-in to the parallel 6-inch line was made and pressure put on to the pipe line for leaks. The end of the line was blanked off, either by welding a cap over it and later cutting it off, or by clamping with a reinforced blind flange, the latter being done only where the pressures were com-

paratively low. In this connection it is regarded as a fitting commentary on the general efficiency of oxy-acetylene welding as now developed, that there were but three or four defective welds that had to be repaired with the torch in the entire 18½ miles aggregating some 2,950 welds—approximately one to every thousand welds. The ratio of pinholes was less than one to every hundred welds, and these were easily closed with a punch.

In the entire line there was but one turn of 90 degrees, and this was accomplished by two mitre welds of 45 degrees each, placed about four or five feet apart. Near this bend was installed an 18-inch expansion sleeve. There were but five expansion sleeves in the entire 18½ miles. The engineers depended primarily on the uniform temperature of the flowing gas to counteract the slight contraction and expansion that would occur in the pipe after finally in place under the ground with gas feeding through it. It has been found that the variations of temperature under operating conditions are very slight in this part of the country compared to those which the work is exposed in construction.

This line is for the purpose of conveying gas from the Elk Hill Wells, near Taft, to the Kern River oil fields in the Bakersfield country. The gas leaves the wells under a pressure of about 350 pounds to the square inch, and reaches its destination at a pressure of from 75 to 150 pounds.

Welding Pipe in the Oil Fields

One of the first pipe line companies to experiment with welding was the Prairie Pipe Line Company, of Independence, Kansas. This company bore the brunt of some of the early failures and for very many years would have nothing whatever to do with welding. It is all the more interesting for this reason to learn that the same company was one of the first to resume experimental work and to finally adopt welding as a standard method of construction for new lines.

The first fifteen miles of 8-inch welded line was laid about two years ago. This company used a 100-lb. portable acetylene generator and worked with five or six welders tying together one-half dozen or more lengths of pipe at each sitting. The welding crew was advanced as rapidly as the work progressed, keeping close on the heels of the lining-up gauge going ahead. Two or three operators trailed the main welding crew, tying in the long sections, the last welder working in a bell hole to tie in the still longer sections when they were rolled into the trench. On this line the company used plain pipe with 60 degree bevels at the ends. The line traversed much difficult country in a district that is rough and hilly. After the work was thoroughly organized the crew advanced at about the rate of one-half mile per day. The total crew comprised eight welders and about twenty-five extra men to line up the pipe and assist in making bonds and getting the slack in the welded line. When completed there were 4,250 welds.

The line was subjected to a cold water test under a pressure of 775 to 800 lbs. and it was found that there were two small leaks in the line. When these were repaired, and the pressure was run up again, the line was found to be in good condition, and it was at once placed in service for the transmission of oil. This was in February, 1921. Up to the present time none of the joints has given the slightest trouble, and as a consequence, the superintendent decided to adopt the welded line as a standard for new construction. Since welded construction was recognized there have been no breaks in welds, the lines have been free from collar leaks and there has been no oil loss whatever.

It should not be assumed, however, that the company in their later pipe line construction followed closely the construction methods pursued in their initial welded line. On the contrary, they made a number of material changes which resulted in greater efficiency and greater economy. One of the principal changes was in the length of the original pipe sections. By making a special arrangement it was found that the mill would supply 8-inch pipe in 40-ft. lengths with the ends beveled to 45 degrees for welding, which made it possible to advance at the rate of slightly more than a half mile a day with only six welders. The force of helpers on the second 15 miles of pipe line was about the same as on the first 15 miles. The second line, which was laid near Shawnee, Okla., was finished without a single leak showing in the welds, but there were a couple of joints that had to be removed and replaced because of pipe sections that were imperfect as manufactured and delivered. These two 15-mile stretches of 8-inch pipe line and 6 miles of 6-inch line have given remarkable satisfaction, no leaks having developed in any of the lines after the repairs noted following the pressure impact tests on the first 8-inch line.

The same company has found welding and cutting very useful in the repair of pipe lines in which there has been more or less severe pitting of certain sections. Where the lines cross districts impregnated with alkali, pitting has been found to be so serious that after a few years entire sections of pipe have to be taken up and replaced. The cutting torch has been found to be invaluable for taking out bad sections and welding has made it possible to insert the new pipe sections with a minimum of expense and delay.

What is considered to be the longest welded pipe line was installed to carry oil from Mexica to Hensley, Texas. This is a distance of approximately 140 miles. In laying this line, the Prairie Pipe Line Company divided the equipment into four sections, each foreman getting a crew of eleven welders, two generator men and a couple of helpers. After carefully checking up the records, the cost per weld on this line was estimated at $2.00. This includes carbide, gas and labor. For protecting the pipe from the action of alkali, it was given a coating of Parolite, which is heated like pitch and poured over the pipe after welding. This liquid is caught under the pipe in a sheet of canvas which is drawn back and forth to assure the liquid adhering to the bottom, sides and top of the pipe.

For river crossings much heavier pipe is used. It runs 43.38 pounds per foot. The welded joint is far superior to the threaded joint in river crossings because of its ability to withstand the vibration of the water which wears out coupling threads.

Organization of Welding Crew: For an extensive pipe line project, welding is accomplished in three stages. First there is the welding crew, having four welders, who weld five lengths of 40-ft. pipe. These are followed by the tie-up welders, who join two of these 200-ft. lengths of pipe. Then the 400-ft. lengths are welded to the line by the "bellhole" welders.

For this work open-hearth pipe, 40 ft. long, having plain ends, beveled toward the inside, is desirable. This pipe is first strung along the route of the line. Ahead of the welding crews, is a force of men, who place this pipe on blocks, five joints in each section, with the ends butted firmly and held securely with clamps. No other preparation is necessary for new pipe, unless it is rusty or dirty, when it is cleaned with a wire brush.

Each welding crew, two of which usually work under the director of one foreman is provided with a generator. This is mounted on a farm wagon. A hoop around the generator is bolted to the wagon bed. Pipes are extended from the generator to the end of the wagon bed, where regulators are installed and hose attached. Each wagon is equipped with an oxygen bottle rack. A generator man is part of each crew.

For each pair of generators, another wagon is equipped with a water tank of 250

gallons capacity. It has a pump, assuring ample water not only for flushing the generator tanks, but also for filling them before a new charge of carbide is put in.

A generator is halted near the middle of the five lengths of pipe to be welded. Two pieces of hose 75 feet long are provided for the welders working at each end of the section. Inside welders have 50-ft. pieces of hose. Each welder finds his joint held by a clamp. He then takes two or three "tacks" in the joint, after which the clamp is removed and sent ahead for the next weld. Half the joint is welded. Then with the aid of helpers, the whole length of pipe is rolled on its blocks and the weld completed. The whole joint is "built-up" with welding rod.

After the welding crew moves on, the tie-up men weld each pair of 200-ft lengths of pipe by similar methods. A portable acetylene tank is provided for each tie-up crew. Two abutting lengths of pipe, each 200 feet long, are held in line by a clamp until sufficient welding has been done for the clamp to be removed. The pipe is rolled on the blocks and the unwelded portion of the joint kept convenient for the welders.

The most difficult part of the process is left to the "bellhole" crew, sometimes one welder but more often two. This name comes from the fact that a hole must be dug beneath the joint for the weld to be made. Behind this crew is frequently several miles of welded line. Consequently it cannot be rolled for the convenience of the welder.

Fig. 11—Left: Welding 75-ft. Lengths. Right: Making the Bell Hole Weld.

Sometimes the pipe has been dragged into the ditch before this weld is made. Again it may be left lying on the ground. In either case a hole must be dug beneath the joint, of sufficient size to allow the welder to work from below. A 400-ft. length of pipe is brought to the several miles of welded line and a "jack" attached to hold it uniform during the weld. This jack consists of two chains and a lever, by which one man can hold the pipe securely. While the pipe is held firmly with this device, two men usually complete the "bellhole" weld one working at the bottom side of his half of the joint, while the other works at the top, reversing positions as they progress. Because of cramped positions when working beneath the pipe, this weld is extremely difficult. Acetylene and oxygen for this welding is supplied from portable tanks.

Cutting Pipes for Special Joints

Cutting pipe for a right angle joint is a simple process if a wire oval, similar to that shown in Fig. 12 is used. These ovals can be made in a series, one for each size of pipe. The proper cutting for the right angle joint is then only a matter of marking with chalk, and following the lines with a cutting torch. The two notches at each side of the oval locate the center of the joint.

Savings Occasioned by Welding

Numerous examples have been published of the savings made in the installation of pipe lines by substituting welding for other methods of making joints. Actual cost figures are always subject to misinterpretation, but the following examples show typical reports of savings, the cost of welded joints being used as the basis for figuring percentages in all cases:

Case	Cost of Welding	Cost of Ordinary Joint	Sizes of Pipe, Inches
1	100	110	12
2	100	500	6
3	100	525	6
4	100	175	6
5	100	200	2 to 16

The savings are especially marked when there are numerous branch lines, offsets, drips, tees, elbows, seals, valves and service lines included in the installation, as the parts for such connections can be quickly fabricated on the spot with a cutting torch and a welding torch.

Welding Small Steel Pipe

In a paper recently read before the A. S. R. E. on the welding of ammonia pipe lines, coils and pressure vessels for ice making and cold storage plants, Mr. C. Wilkie gives the following useful instructions for making leak proof joints in small steel pipe:

In welded ammonia pipe lines and coils the use of expensive fittings is elimina.ed which greatly reduces the first cost of an installation.

The life of the pipe lines and coils is increased from 20 to 50 per cent. This is especially true in small pipe where 40 to 50 per cent of the metal involved is cut away by threading and the fact that there

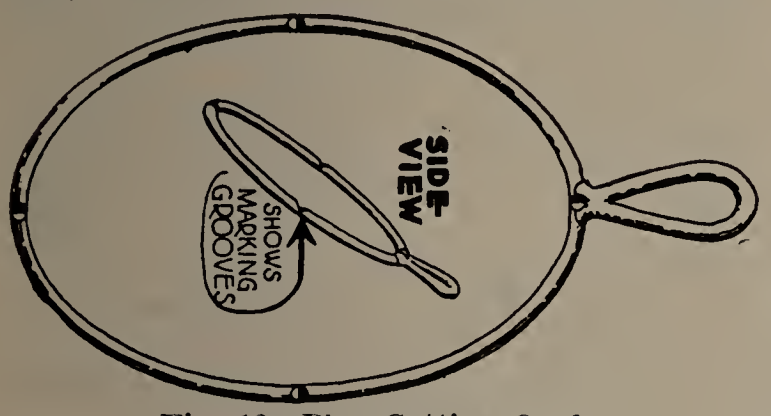


Fig. 12—Pipe Cutting Oval.

are two or three threads exposed behind each fitting, at which point the first leak usually appears.

It is customary to use hair-pin bends made up from 1¼ in. standard pipe with 4½ in. and 5 in. centers in ice freezing tanks; the thickness of the pipe wall on the back of these bends is reduced from 40 to 60 per cent depending upon the nature of the heat. This defect can be overcome by the use of welded return bends which will cost less than fittings.

The extremely low cost of maintenance on welded lines and coils is reduced to a minimum, for when once in position and welded, there are no repairs to be made.

Welded lines can be installed in less time than where fittings are used, and are very much cheaper.

Another interesting saving effected in welded lines and coils is that of ammonia consumption. For instance, an installation of piping that would require 10,000 welds in order to eliminate all thread and gasket joints would, however, at the same time eliminate from 30,000 to 40,000 leak points, depending upon the number of different types of fittings used. With the leak points eliminated, or as nearly so as possible, it is clear that the ammonia consumption will be reduced.

Preparing Pipe for Welding

It is just as important to prepare pipe properly for welding as it is to weld it well. It is advisable to bevel or scarf all standard pipe above 2 in. and all extra heavy pipe above 1¼ in. The scarfing can be done with the cutting torch by laying the cutting tip on the pipe at the proper angle so as to leave the metal at the bottom of the scarf about ⅛-in. thick. The scarf should be about 1½ times the thickness of the metal because a 45 degree scarf does not seem to give enough fusion area in the base metal. This does not mean that a 100 per cent weld cannot be made where the metal is scarfed at 45 degrees. It can be made, but it is found that a certain per cent of specimens when tested will break along the line of the scarf. To overcome this defect it is necessary to make the scarf at a higher degree in order to get more fusion area. Then, however, the weld will break in the center. To prevent this it is necessary to reinforce the weld by building it up, or use an alloy such as the nickel steel for the filler rod. In welding pipe together care should be taken in cutting to get the ends square—a greater opening on one side will cause an uneven shrinkage and the pipe will not be straight. This is very important in welding large pipe where a considerable amount of metal is involved.

When welding heads in pipe, traps, oil separators and receivers, small pipe where flat heads are used, the head plate should be scarfed at 45 degrees around the edge and placed inside the pipe and the proper distance so that 1½ times the thickness of the pipe wall can be crimped over onto the head plate, and weld to seal the joint. (See Fig. 14.)

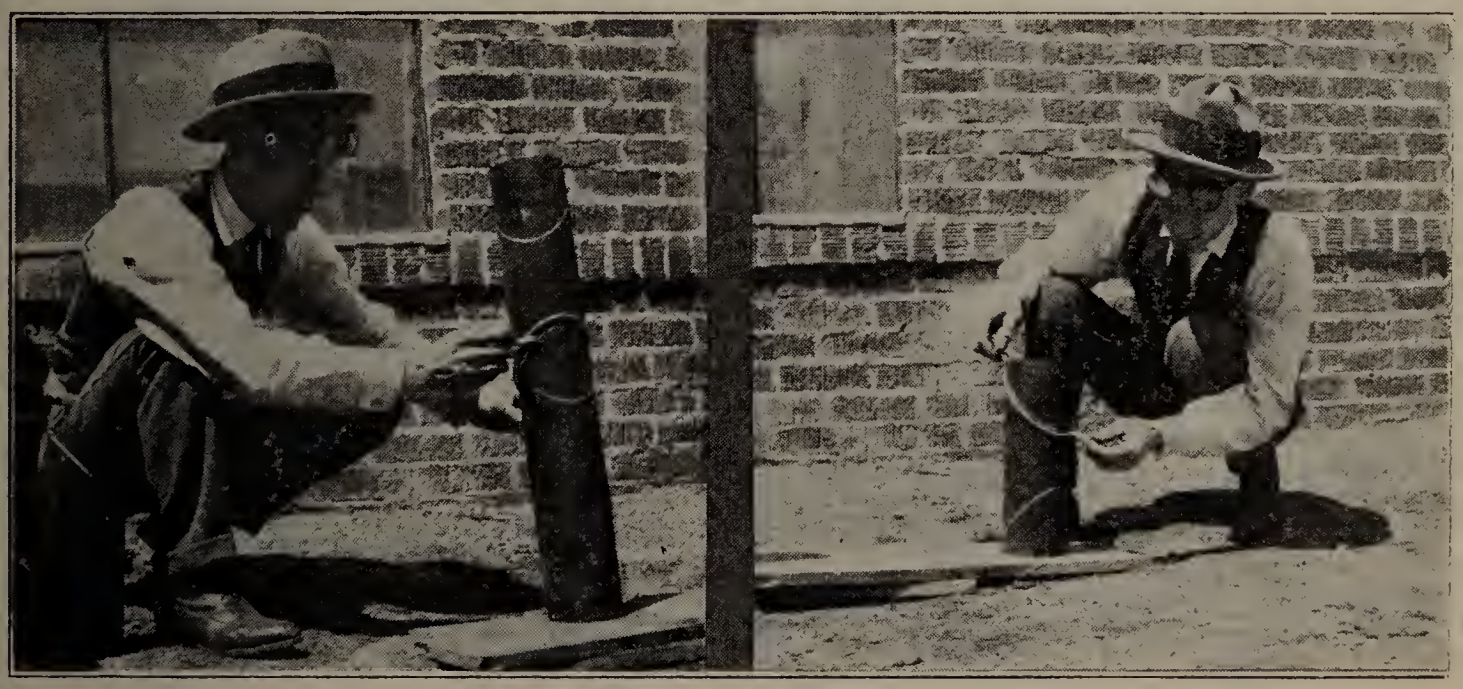


Fig. 13—The Pipe Cutting Oval in Use.

For standard bumped heads they can be placed inside the pipe and welded in the same manner as the flat heads (See Fig. 15), or have the diameter of the heads made the same as that of pipe and make butt welds.

In making reducers it is necessary to crimp the larger pipe, afterwards inserting the smaller pipe or nipple. This fitting is the most expensive of all to make, as it is necessary to make a very wide weld in order to get the desired thickness at the center. (See Fig. 16.)

90-degree elbows are very simple fittings to make, there being two 45-degree welds. The length of the center piece on the inside is equal to one-half the diameter of the pipe, so that all elbows are of a uniform size. (See Fig. 17.)

Tees are made by first cutting the nipple to a saddle form to fit the pipe. The nipple then serves as a pattern for marking off the hole. After cutting the hole it is scarfed to 45 degrees on the sides and two times the thickness of the metal on top of the pipe. Patterns are used for laying out tees and elbows and a perfect fit is obtained without doing any trimming. (See Fig. 18.)

Where welded elbows or tees are made in close work with flanges, and the fittings are not a true 90 degree, it is an easy matter to face the flanges by heating a ring around the pipe a short distance away from the flange and then tighten up the bolts.

In making welded return-bends the pipe and two return pieces are sawed at the

proper angle, and three 60-degree welds are required to complete the half circle.

There are several advantages in the welded return-bend.

1st. A more compact coil can be had without thread joints, as 2¼ in. centers can be obtained with 1¼ in. pipe and 3 in. centers with 2 in. pipe.

2nd. The pump head is reduced about 30 per cent in the height of the coil.

3rd. The thickness of the metal in the back of the bend is not reduced.

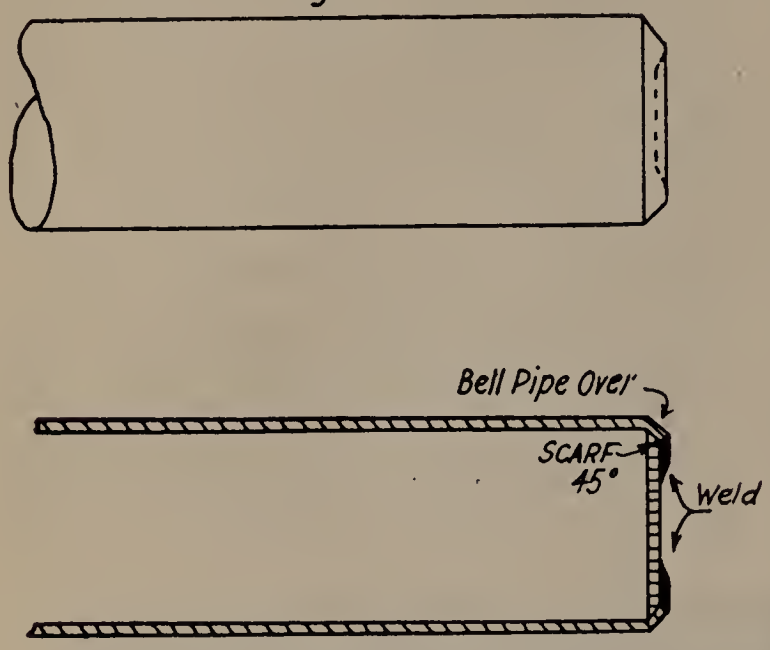
4th. Drip-strips are eliminated due to close pipe centers or proper centers.

5th. Welded bends cost less than screwed fittings.

6th. The life of the coil is dependent on the life of the pipe and not on a thread joint.

7th. A defective pipe can be renewed without taking the coil apart. (See Fig. 19.)

Fig. 2



WELDED HEAD IN PIPE

Fig. 14.

The Efficiency of Welded Pipe Joints

It is clear that leaks do not indicate low efficiency. Anyone with the proper knowledge of welding steel can melt into a defective weld and afterwards state the exact cause of the leak. As a rule there are four reasons for a leaky weld:

First—The lack of fusion of the metal involved.

Second—Oxidation, or an excess amount of oxygen fed through the torch.

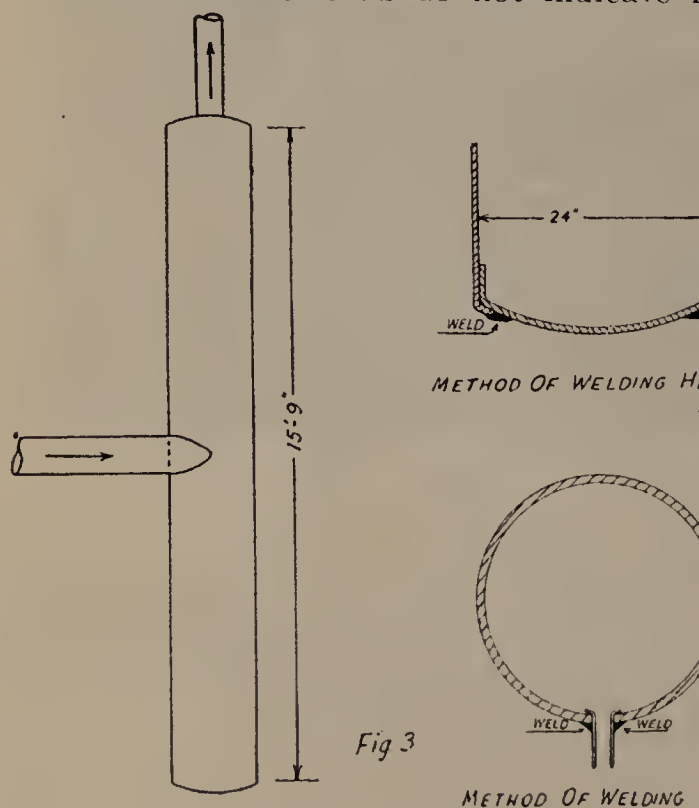


Fig 3

METHOD OF WELDING HEAD

METHOD OF WELDING NIPPLE

ALL WELDED OIL SEPARATOR

Fig. 15.

Third—Carbonization; that is, an excess amount of acetylene fed through the torch.

A carbonized weld is very porus and can be rewelded and the quality restored to some extent by using a lightly oxidizing flame.

Fourth—Practically all welders weld forward; that is, the flame follows the rod, and when welding pipe, especially small pipe, there is danger of overheating when the weld is near completion. In case the weld is overheated at this point it will be porus and will leak. Overheating will sometimes cause the pipe to leak as far as ½ in. away from the weld. But by welding backwards with the rod following the flame, and, by slightly moving the rod, causing the metal to be agitated, which will overcome the porous effect caused by overheating, the weld will be compact and nonporous.

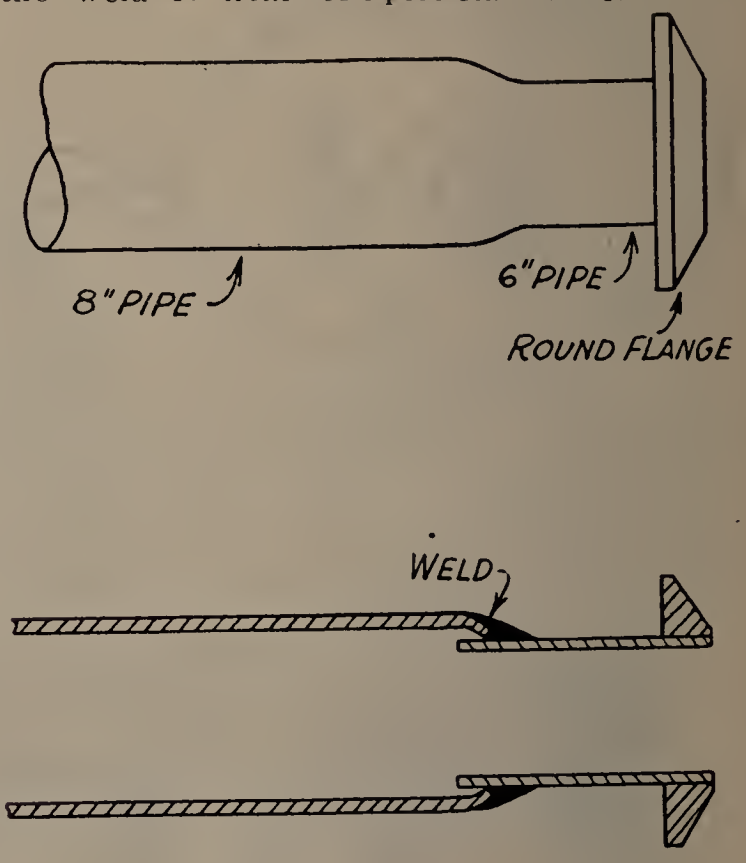


Fig. 4

WELDED REDUCER

Fig. 16.

Some welders insist on making a smooth surfaced weld, that is, dressing the surface of the weld as it is completed, and in some cases they are asked to do this. But beware of such welds. A weld can be ever so porous and by melting into the surface, say 1/16-in., with the proper flame in order to dress the weld, the chances are it will stand a high pressure test without showing any signs of leaking. The possibility of any leaks should be overcome with the first metal that is placed in a welded pipe joint, as it is possible to make a weld that would be 100 per cent efficient as far as tensile strength is concerned, and yet be porous to within 1/16-in. or probably 1/8-in. of the surface, and will in time leak due to corrosion. On the other hand where fittings are used the same thing can happen and does happen. The possibility of a thread joint not leaking may be depending upon one particular thread, and in the course of time it will leak.

As a rule in welding pipe which has a heavy wall the average welder will get the most defective metal at the bottom of the weld. This is due to the fact that the sides of the V are broken down first, causing iron oxide to be washed to the bottom of the weld. Tests have shown the tensile strength of the first ⅛-in. or 3/16 in. of metal in a weld made in this manner to be as low as 19,000 lbs. per sq. in., whereas the same area near the surface of the weld would have a tensile strength of 51,000 lbs. per sq. in.

This defect can easily be overcome. Since the metal is ⅛- in. thick at the bottom of the scarf, it is clear that by melting through the V, and at the same time adding additional welding metal, the bottom half of the weld would be as sound as the top half, and by welding the bottom of the V a distance of from 1 in. to 1½ in., before the sides at the top are melted down, it is an easy matter then, providing the torch is properly handled to wash practically all the iron oxide to the surface of the weld. This method alone will increase the efficiency of a single V weld from 8 to 12 per cent. A double V weld would evidently be more efficient than a single V, but in welding pipe it would be impossible to make a double V weld.

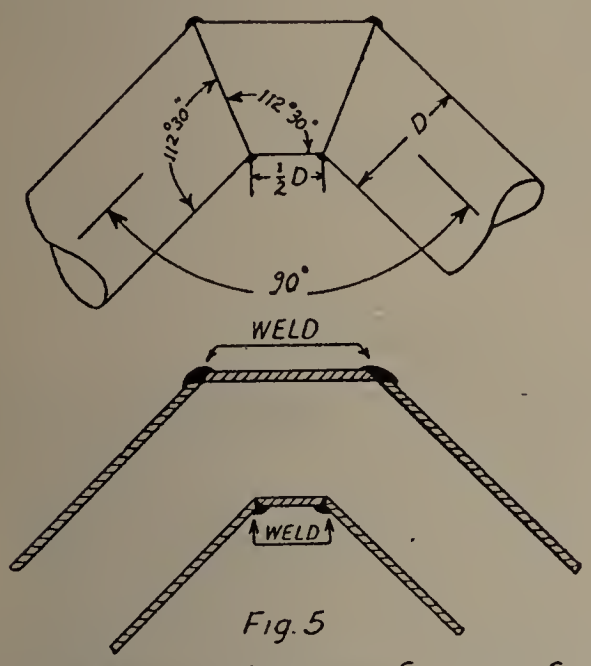


Fig. 5

WELDED ELBOW AND SECTION SHOWING SCARF

Fig. 17.

The improper cleaning of the scarfs, providing this work is done with the cutting torch, will affect the quality of a weld. It is important to maintain a neutral flame while scarfing in order to eliminate, as nearly as possible, any carbonizing action on the surface of the metal. In welding small pipe, say up to 2 in. in diameter, where scarfing is unnecessary, the weld should be made as rapidly as possible, providing the flame is of ample size to melt through the pipe wall in a reasonable length of time. When melting into the pipe the flame automatically scarfs the metal to 1½ to 2 times its thickness, and by having the welding wire follow the flame it is an easy matter to tell when the pipe is welded through, as the bottom of the V, which is made by the flame, will become soft, which indicates that the metal is at the fusing point on the inner side, and the necessary amount of welding metal is added to reinforce the weld from 10 to 25 per cent, depending upon the composition of welding wire used.

Small pipe welds very seldom leak due to improper fusion of the metal, since the flame melts practically through the pipe. If the proper flame is used and the metal is not overheated, it is much easier to make 100 per cent welds in small pipe than in large pipe with the single V weld. In fact, there is no excuse for a small pipe weld not being 100 per cent in every respect.

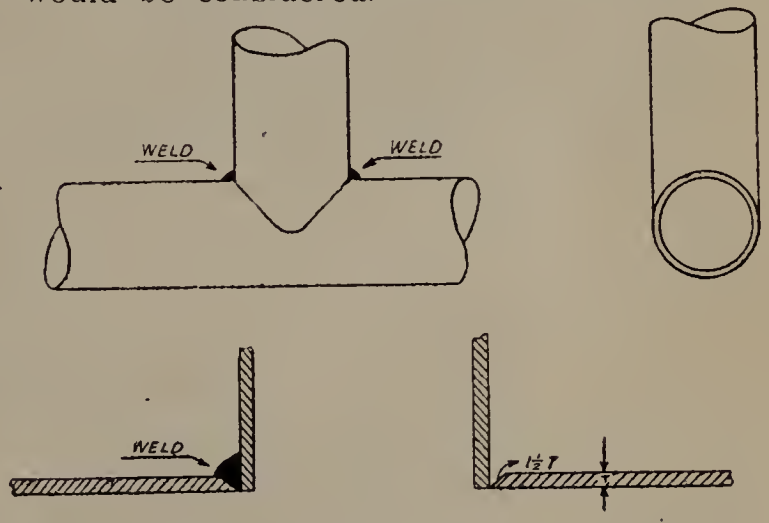
Where fittings are made in pipe lines in position, the strains can be relieved to some extent by heating a ring around the pipe on either side of the fitting. The width of the heat should not be, in any case, less than one-half the diameter of the pipe. There should be sufficient heat applied to bring the pipe up to a bending temperature, and the heat should be as even as possible the entire circumference of the pipe. The necessary heat can be applied from a welding torch, and if necessary two torches can be used.

Coal oil blow torches can be employed and the welded fittings preheated to the proper temperature to relieve welding strains—a temperature of 1,050 degrees F. would probably be sufficient. (A. S. M. E. Boiler Code.) The fitting, including the weld, or welds, should be at an even temperature (or as nearly so as possible), and covered with asbestos paper or any insulating material that would serve the purpose of allowing the fitting or welded joint to cool slowly.

Welds made in small pipe, up to and including 1¼ in., as a rule, are made in from two to four minutes' time, and when completed the welded section is at the annealing temperature. In the case of very small pipe, say up to 1 in. standard, the welded section is at a higher temperature than is necessary for annealing. It is clear that welds made in small pipe would receive a fair degree of preheating from the torch, thus eliminating the necessity of annealing.

In considering the construction of ammonia receivers and oil separators, to be made up in plants, as a rule it is necessary to use pipe for the shells of such vessels. Ice and cold storage plants do not have the necessary equipment for rolling such shells, providing the longitudinal seams are welded, nor are they prepared to anneal any part of vessels made from pipe as large as 24-in. diameter. Standard bumped heads of the proper thickness and properly crimped in the pipe, and welded, would not require annealing.

The nipples for gauge cocks, and liquid in and outlet connections, can be screwed into the pipe and welded for sealing, or such nipples can be flanged and inserted from the inside before the heads are fitted. A vessel of this design would not require any annealing. Aside from this, the possibility of getting such vessels covered by insurance would be considered.



WELDED TEE AND SECTION SHOWING SCARF

Fig 6

Fig. 18.

There are several methods by which long headers can be kept straight when it is necessary to weld in a number of nipples.

1st. Preheat the header in a forge fire as the nipples are being welded in. The labor cost is considerable, due to the fact that it is necessary to furnish the welder with a helper, as care should be taken to keep the header in a level position. Besides, the welder is compelled to stand over a forge fire which is not a pleasant thing to do.

2nd. Weld in all nipples, allowing the header to expand and contract at will. When the welding of all nipples is completed and the header allowed to cool, and it can be straightened very easily by turning upside down and with the welding torch spot heat just opposite each nipple that was welded, applying, as nearly as possible, the same heat that was applied when welding the nipples. After the header is allowed to cool it will be sufficiently straight.

3rd. In shops where the necessary equipment is at hand the proper curve is put in the pipe and welding the nipples will cause the header to become straight. (See Fig. 20.)

The Requirements of a First Class Pipe Welder

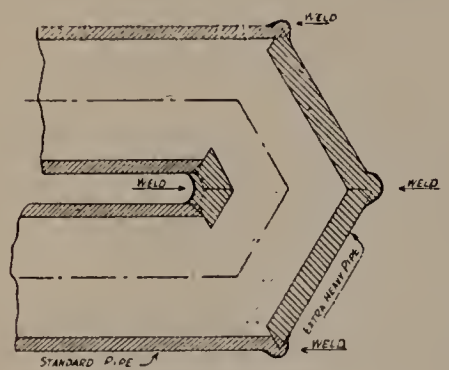
1st. A welder should be ingenious and he must be honest.

2nd. A welder should have a thorough knowledge of the composition of steel pipe.

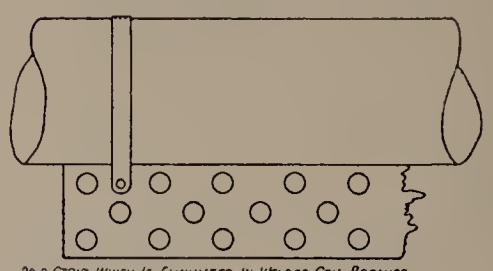
3rd. He should be able to select the proper welding wire to be used.

Repairing Broken Pipe Under Pressure

In some cases it will be found that water mains become pitted in service, and while there are several ways of making repairs, a more permanent repair can be made by welding. After thoroughly cleaning the pipe, plug up all holes with pine plug, cut off the plug with a hacksaw flush with the surface of the pipe, then cover with a metal cap held in place by welding. The patch



SECTION OF WELDED BAND SHOWING EXTRA HEAVY PIPE
Fig 8


DRIP STRIP WHICH IS ELIMINATED IN WELDED COIL BECAUSE OF CLOSE PIPE CENTERS
Fig 9

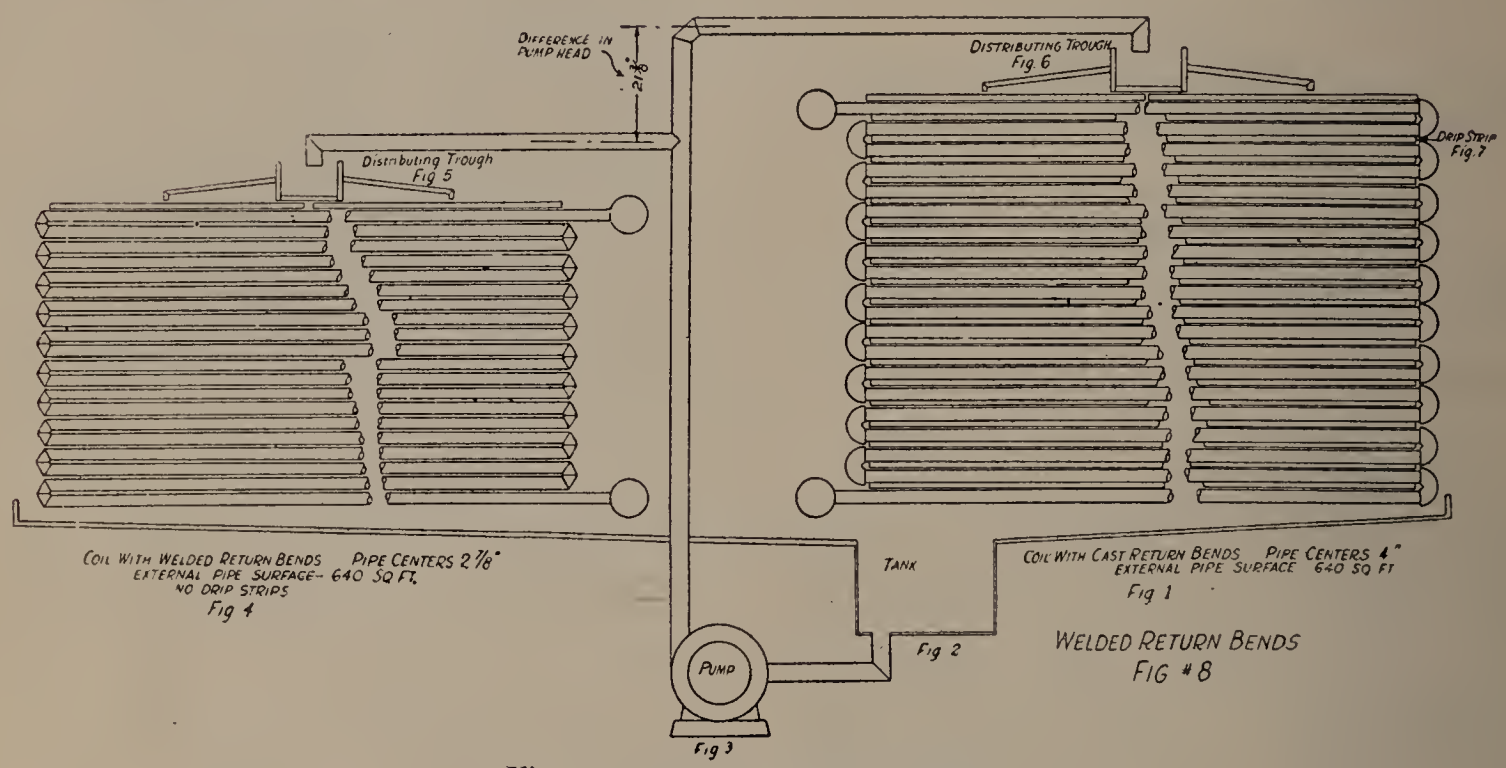


Fig. 19—Welded Return Bends.

4th. He should experience the testing of welded specimens made with oxidizing, carbonizing and neutral flame. High pressure air, tensile and bending test should be made on such specimens to determine the extent to which a weld can be carbonized or oxidized without decreasing the quality beyond a safe point.

5th. A welder should be able to make a 100 per cent weld on pipe in a vertical or horizontal position.

6th. He should be able to select the proper size welding tip for any given size pipe.

7th. He should be able to lay out patterns to be used in cutting out tees, elbows and reurn bends.

8th. A welder should be well versed as to the construction of at least three makes of the leading welding equipment.

9th. He should be able to keep his helper, or helpers, busy at all times.

10th. A welder should have a thorough knowledge of taking care of welding strains in pipe lines, and furthermore he should know the few methods by which strains are prevented to some extent.

11th. He should be able to read blue prints of prospective pipe installations.

12th. A welder should have a thorough knowledge of estimating the quantity of acetylene and oxygen consumed in doing any particular piece of work.

should be slightly concave. The welding should extend far enough over the edges to get a firm hold on the pipe. Where a number of pits occur in one spot, a single patch can be made to cover them.

Welding a High Pressure Steam Line

The Philadelphia Electric Company recently constructed a 12-in. steam and a 3-in. water return line, about 2,200 ft. in length, which presents some unusual features, one of which, the welding of the piping, was described in a paper read before the American Welding Society by E. L. Hopping.

In the construction of the two lines, welded joints were used wherever possible. In the 12-in. pipe, which is full-weight steel (⅜ in. thick) there are 89 welded joints and 33 flanged joints. In the 3-in. line, which is standard weight steel (¼ in. thick), there are 92 welded joints and 27 flanged joints. The two lines were constructed in a concrete tunnel having inside dimensions of 2 ft. 7 in. in height and 2 ft. 7 in. in width. The bottom and sides were built first and the pipe lines constructed inside this part of the tunnel, after which the top slab was poured and the excavation above the tunnel filled in.

Each pipe line is supported at about 17-ft. intervals, on slding or rolling supports. Alternate supports are anchored to the bottom of the concrete tunnel and so constructed that they can slide horizontally to take care

of the expansion of the pipe. The purpose of this construction is to hold the pipe in alignment, especially when steam is being turned into the line, at which time there is a tendency for the pipe to bend on account of unequal heating. In the center of each section of pipe, or at intervals of about 135 ft., solid anchors are provided so that the pipe expansion will travel from the center to the ends of the pipe, where expansion joints are provided.

Since it was necessary in running the line through the street, to change the elevation at a number of places in order to clear obstacles, quite a few pockets were formed, which in all cases are drained through traps. After the piping had been assembled and tested, it was covered with 3 inches of magnesia insulation and a layer of heavy roofing felt outside of the insulation.

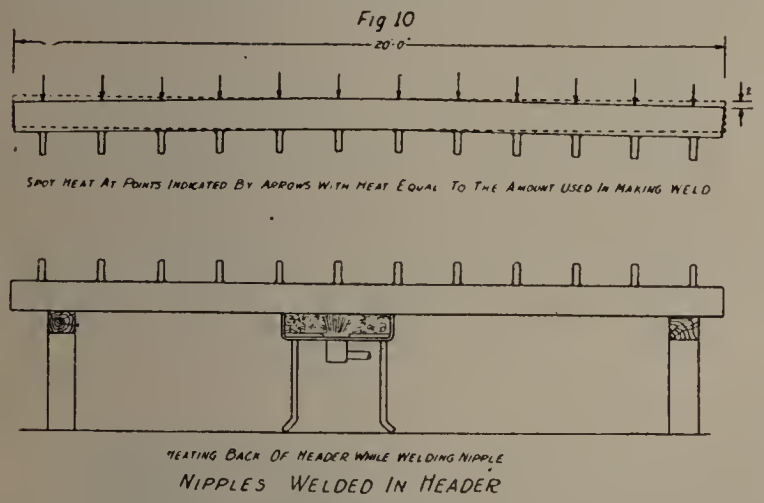


Fig. 20.

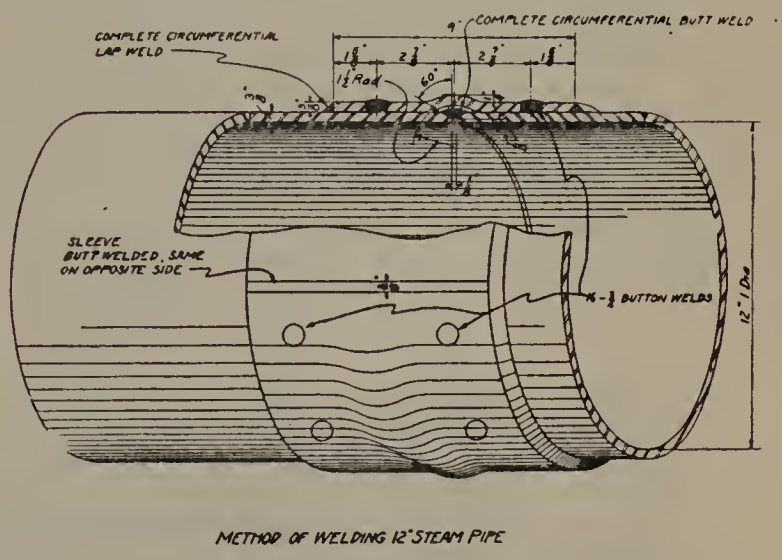
The purpose of this type of insulation was primarily, to eliminate, as far as possible, the heat radiation into the surrounding soil, and thus guard against serious heating of electric cables, which some types of construction the heating of the soil has been so excessive as to cause failures in the electric cables.

Very often underground steam lines have been constructed with screwed and various other types of flanged joints. Such joints frequently become leaky and necessitate tearing up the street, with its attendant inconvenience to the public and expense to the owner of the steam line. It was, therefore, felt in this case to be very desirable, especially on account of the high pressure (130 lb.) carried in the line, to make the construction such that it would give a minimum amount of trouble from leaky joints. Another point considered in the discussion of the type of joints to be used in the line was the item of cost. While it was desired to prevent as far as possible, any leaking at the joints it was not considered desirable to spend an excessive amount of money to secure freedom from this trouble.

After a great deal of discussion as to welded joints it was decided that if such a joint were used it would be necessary, in order to secure the maximum protection against failure, to reinforce each joint with an external sleeve welded securely to the two ends of pipe. The accompanying illustration shows in detail the construction of the 12-in. joint. See Fig. 21.)

In discussing the welding of this type of joint with the company which performed this part of the work, their advice was followed in making the butt weld with the oxy-acetylene process and making the sleeve welds electrically. It was felt that welds made with the oxy-acetylene process would be more dense and therefore better able to withstand the steam pressure than would welds made electrically. Since the welding of the sleeves to the pipe was principally for the purpose of giving mechanical strength to the joint, this part of the work was done with the electric process, with which there was much less liability of distorting the butt welded joints, as the area of the pipe which must be heated to a high degree to obtain fusion is localized to the part immediately surrounding the electrode.

In the construction of this line it was necessary at certain points to use steel fittings, and at these points Vanstone flanges were used in making the joint between the pipe and the fittings. It was also necessary to provide expansion joints at about 135-ft. intervals, which necessitated the use of Vanstone joints at these points. In between the flanged joints on the piping there were a number of welded joints which in nearly every case were found to be tight at the butt weld under a test pressure of 750 lb. per sq. in. In all cases where leaks occurred, or where sweating at the weld took place under the test pressure, the joints were re-welded and again tested. After the butt welds were made tight the sleeves were applied to the



METHOD OF WELDING 12" STEAM PIPE

Fig. 21.

joints. Only the first section of piping, containing six welds, was tested after the sleeve had been applied and all the joints appeared to be satisfactory. This test was made to determine whether the stresses produced in welding the sleeves to the pipe had in any way affected the butt weld.

In making the butt welds on the piping two sections of pipe were brought together, giving the proper spacing between the ends of the piping, and then one-half section of the sleeve was temporarily clamped to the pipe ends so as to hold the pipes in proper alignment. This allowed half of the circumference of the butt joint to be welded while the clamps were in position. After the half circumference was completed the half section of sleeve was removed and the piping was turned on its supports so that the other half of the circumference was brought to the top. This method allowed most of the welding to be done from above. There were some cases, however, where bends occurred in the line which would not allow for turning the piping. In these cases it was necessary to raise the pipe in the tunnel so that there was 3 ft. between the bottom of the pipe and the bottom of the tunnel, in which space the welder had to perform his work. The welds made from underneath proved in all cases to be as good as those made from above, although it took more time to do the welding from this position, especially when using the oxy-acetylene process. In making the electric welds the speed when working from underneath was almost equal to the speed when working from above. The average total time consumed in making one 12-in. weld, including both the butt welds and welding of the sleeve was three (3) hours.

Welded Water Pipe Lines

The experience of the Butte, Montana, Water Company in laying several miles of large diameter water pipe operating under heads of from 500 to 800 feet, indicate possibilities in this field. This construction was undertaken in spite of the fact that there was no precedent on which to base provision for ex-

pansion and contraction in a line of this size. For pressures higher than a 300 foot head lap, welded steel pipe was adopted. The thickness of the steel varied to conform to pressure as follows:

Linear Feet	Diameter in Inches	Thickness in Fractions of an Inch
22,388	24	0.33
2,903	26	0.362
360	26	0.4375
443	26	0.5

The pipe came in varying lengths, averaging about 17.5 feet with the ends all beveled for welding.

The rough country over which the pipe was laid presented many construction difficulties. There were several long grades and some real steep hillsides.

In cases where the grade of the pipe line was uniform, the pipe was placed on skids alongside the ditch where it could be turned for welding so as to keep the weld on top and welded together into the lengths of 120 feet. These long lengths were rolled over the trench, welded together before lowering so as to further reduce the amount of overhead welding. The free end was left on skids above the ditch when the welding end was lowered so that the next 120 foot section could be welded on when finished. After the welding was finished an inspector went inside of the pipe, chipped off the excess metal and painted the welds with a preservative paint. The pipe was then carefully covered and tamped, and as soon as possible water was turned into it for leaks. It was found that most of the leaks which developed were small cracks on top caused by the settlement of the pipe after it was laid.

An important point in the procedure of welding this pipe was the thorough heating of the pipe for about six inches on each side of the joint before starting the weld. During the welding the ends of the joining pipe sections were held together by collars until the pipe was tacked together at four places with tacks about 4 inches long. Two welders worked together on each joint coming towards each other from opposite sides of the pipe, starting at the bottom and carefully working up to the outside diameter, taking care to fill the bevels entirely full of metal without permitting any of it to run inside of the pipe.

On account of the small variation in the diameter of the pipe, the uneven alignment of the pipe over the rough country, and the settling of the pipe after the line was constructed, only a few expansion joints were necessary, eight of these were necessary in the original installation and six more were added later where it was found that strains had developed in the pipe line.

A Pipe Welding Crew in the Oil Fields

Tank Welding

IN practically every industry where tanks are used, it is becoming common practice to use welded construction in place of the old type of riveted construction. The two welding processes used are arc welding and gas welding, and they are employed alike in the fabrication of storage tanks and pressure tanks. In general it is a question of welding long seams in rolled steel plate, and the common precautions for securing good fusion and thorough penetration apply, the operator having his choice of the rigid or non-rigid methods of welding to avoid warpage due to contraction strains. In the present discussion, therefore, it will be necessary only to describe a variety of typical tank welding jobs to indicate the range of application of the welding processes.

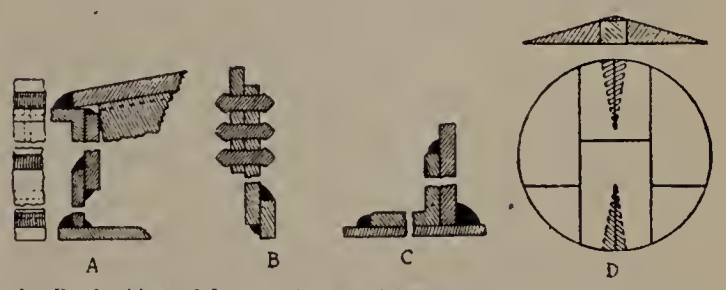
Pressure Tanks

In the oil refining industry, there are constantly being used tanks which have to stand a working pressure of 100 lbs. to the square inch while heated to a temperature of sometimes as high as 750°. These tanks are about 44 inches long and 20 inches in diameter. They are made from ½ inch steel plate which is rolled to the desired shape. The ends of the tanks are dished and inserted with the concave surface on the inside. The double bevel design is used thruout and when the welding is started on the longitudinal seam, an opening of ⅝ inch for every foot of the length of the seam is left at the far end. This refers to tanks which are welded by the oxy-acetylene process. When the electric arc process is used, the opening can be reduced to about ⅜ of an inch for every foot of length of the seam. Both processes are commonly used in the manufacture of these tanks and in both cases, only enough reinforcement is made on the seam weld to make sure that the thickness of the metal has not been reduced at any point. The added metal is made to lap over about ⅛ inch at each side of the V. So many of these tanks are used and it is so important that the tanks be able to stand the required working pressure that it is customary to test the results regularly. These tests include filling with hot oil and applying 500 lbs. of pressure and then hammering with a heavy sledge. More severe tests have been made in which the pressures have been run up to 1800 lbs without causing any ruptures either in the weld or in the metal near the weld. The only unusual precaution taken is for the purpose of securing thorough penetration when welding in the head of the tank. The head itself is inserted about ½ inch below the edge of the cylinder. The welder is taught to weld 3 or 4 inches lightly, then go over the same portion of the seam until he has filled it completely to the top. Then repeat the process on the next 3 or 4 inches and continue in this manner until the seam is complete.

ELECTRICALLY WELDED TANKS

Storage Tanks

In designing a welded tank it is proper to follow the fundamental outline, such as the lapping of the plates, of the riveted tank construction, for the present time. New methods of welded construction of tanks are now being developed, which will involve radical changes and seem to offer great possibilities. The only present variations are details and simplifications which are special to the adoption of the welded construction. These details include the elimination of rivet holes, butt-straps, gusset plates, angles, fairing of plates and a reduction in the laps of the plates. The plates do not have to be fabricated excepting in so far as the rolling is concerned.



A. Roof, Side and Bottom Welds of 500 Barrel Tank. B. Comparison of Rivets and Welds. C. Side and Bottom Joint of 5,000 Barrel Tank D. Roof of 500 Barrel Tank.

Fig. 1—Comparison of Riveted and Welded Designs

Further, inasmuch as the welded lap joints are of 100 per cent or more strength, the plates in the shell can be lightened 15 per cent. The result should still be a structure 10 to 20 per cent stronger than the present standard of riveted tanks.

The thickness of the bottom and top plates is determined by practice and until it has been demonstrated over a period of years that the corrosion of welded bottoms and tops is less than that of riveted bottoms and tops, it is doubtful whether it will be permissible to reduce the thickness of plate of this portion of the tanks. The skin of the plates of bottoms and tops being practically unbroken, it is reasonable to assume that these parts of the tanks will have considerably longer life than those of the present standards.

The electrically welded tank is a homogeneous structure throughout. The joints are absolutely tight and will stay tight over a period of years and after a number of temperature changes and after the tanks have been filled and emptied a number of times. No initial strains are put on the bottom, as it is welded in place.

The life of a welded tank must be estimated as being at least twice that of a riveted tank, for the reason that the skin of the plates is not broken, and because the volume of the welds provides a much larger factor of safety against corrosion. Welded tanks built on a concrete foundation can be set right on this foundation without an intermediate layer or cushion. Riveted tanks will, if set directly on a concrete foundation, rest on the rivet heads and cause undue strain on these. The electrically welded roof construction is gas tight and as is known, the saving in insurance premiums on gas tight roofs is considerable. In fact, after the advantages of the welded construction have become more generally known, it is reasonable to assume that the insurance premiums on welded tanks will be lower than those on riveted tanks, on account of reduced fire risk.

Paint will only be needed as the old paint is destroyed through age and weather. Painting on account of discoloration caused by seepage will be eliminated. In the refineries, where tanks are painted white, the saving in the paint bill will amount to considerable. The saving in crude oil over a period of years by the use of these absolutely tight tanks will run into large amounts. The savings in volatile liquids from evaporation, seepage and leakage, can hardly be estimated, and will, over a period of years, run into large sums of money.

Following are descriptions prepared by William Schenstrom for the American Welding Society, of the methods of constructing a number of different storage tanks by electric welding:

100 Barrel Tank

9 ft. diameter, 9 ft. high of 5.5 lb. plate (10 gauge). 1½ in. laps throughout, welded from one side only. No chipping and caulking. The bottom and top are in two halves. The shell in six vertical plates. The plates rolled to shape. The plates punched for bolt holes. Two bolt holes every 30 in. and at the corners. Welded with .134 in. diameter electrodes Current value about 125 amperes. Average speed down hand welding 9 ft. Average speed vertical welding 4 ft.

These tanks are erected by suspending an angle iron ring above the tank with six small blocks to catch each of the vertical plates and to hold them in place for bolting up and fastening to the bottom. Next, the top is put into place and bolted up. The tank is then laid on a cradle in a horizontal position and welded throughout from the outside only. The tank is turned so that all vertical seams of the finished tank are welded in a down hand position, as well as the cross seams of the top and bottom. Leaving the tank on the cradle, the tank is turned as the work progresses. The circumferential joints between the top and shell, and the bottom and shell are welded in a vertical position, as are the fittings. The bolts are left in the tank and are welded to the tank from the outside.

500-Barrel Tank

15 ft. diameter, 16 ft. high of 5.5 lb. plate (10 gauge) blue sheet steel. 1½ in. laps throughout, welded from both sides, excepting roof, which was welded from one side only, to make it gas tight. No strains on the roof. Size of sheets, 4x11 ft. No chipping and caulking. The bottom and top are in three courses. The plates were not rolled to shape. Six bolt holes. Welded with .134 in. diameter electrodes. Current value, 125 amperes. Average speed down hand welding, 10 ft. per hour. Average speed vertical welding, 5 ft. per hour.

The bottom plates were laid out flat on the foundation, which was graded in the usual way and welded from one side. After this was complete, the bottom was turned over and welded from the other side.

The shell was made in a different way from the ordinary procedure. Instead of being built in several courses it was built in one single course, giving only vertical seams in the shell, on a barrel stave idea.

The plates of the shell were laid out and welded together flat on the ground, so as to make two halves. One-half of the shell was then raised by means of a gin pole and one corner of it tack-welded to the bottom.

The ends of a turn buckle were fastened to the outside ends of this half of the shell about half way up, by means of clips that were welded on to the shell. By lightening this turn buckle the shell was forced into place and tack-welded as it got into the proper position on the bottom.

The other half of the shell was raised in a similar manner and tack-welded in position.

This left the upper part of the shell out of shape. A cable loop was then put around the top of the shell. By tightening this the shell was forced together.

A 6-inch I-beam on edge, specially prepared with bolt holes and the web removed in way of the bolt holes, was fastened to the outside of the shell along the length of the vertical shell seam. A similar I-beam was fastened on the inside of the same seam.

There were three holes in each of these I-beams, and corresponding holes in the shell of the tank. With these I-beams, the edges of the shell were forced into position and welded.

After the vertical seams had been welded outside, the I-beams were removed and the inside vertical seams welded up.

These bolt holes, which were the only holes in the whole tank were then welded up. The joint between the bottom and the shell was made by setting the shell on the bottom, and consisted of one inside and one outside weld without any angle iron. The outside weld being the heavier.

A 2x2x¼-inch angle iron was welded all around the top of the shell, heel and toe.

The roof was welded in three courses. The ends of the center course were slit in the middle, a V-shaped piece being cut out at each end. A 12-inch high block was put under the middle of the center course, which gave the roof the proper pitch and in this position the slits were closed and welded. This course was then put in place and welded to the top angle and the other courses lapped to the center course and welded to it and the top angle. There was no frame under this roof.

The fittings were welded in the ordinary way.

The tank was filled with kerosene on completion and found absolutely tight without a leak or sweat of any kind.

A number of similar tanks have been successfully welded.

5,000 Barrel Tank

43 feet diameter, 20 feet high. Bottom of $\frac{3}{16}$-inch plate. First course ¼-inch plate. Second course $\frac{3}{16}$-inch plate. Third course $\frac{1}{4}$-inch plate. Fourth course $\frac{5}{32}$ inch. Roof $\frac{3}{16}$-inch plate. Size of shell plates 5x14 feet. 1½ inch laps throughout, welded from one side in top and bottom, from two sides in the shell, the heavier weld being on the outside and in down hand position. No chipping and caulking. The plates were rolled. Bolt holes every 36 inches. $\frac{3}{16}$-inch plate and over welded with .165-inch dia. electrodes. Current value about 145 amperes. Plates under $\frac{3}{16}$-inch welded with .134-inch diam. electrodes. Current value 125 amperes. Average speed down hand welding 8 feet per hour. Average speed vertical welding 4 feet per hour.

This tank was erected according to the standard for riveted tanks, in courses and each course was bolted together before being welded, by bolts every 3 feet.

A 2x2x¼-inch angle iron was laid on the the bottom along this outside edge, leaving a ¾-inch space between the angle and outside edge of the bottom. The bottom flange of angle was welded to bottom.

The first course set on the bottom and backed against the angle and course welded to the bottom all the way around the side by a ½-inch weld. The angle welded to this course from the inside of a ¼-inch weld.

A 2-inch lap between each two courses. The outside welds were made for strength. The inside welds to seal the joint between the two plates.

The plates were scarfed where three plates came together.

The joints were simply welded in the ordinary way.

The top angle 2x2x¼-inch was welded heel and toe all around.

The roof was of the ordinary type of steel roof with a center and radial plates.

The angles and I-beams and roof construction were all welded in the simplest way, according to common practice, developed in structural welding work. (See "Structural Steel.")

Rectilinear Tanks

Figure 2 shows three methods of making rectilinear shapes; one well known method of cutting out and bending up and welding along the edges. This method is satisfactory for comparatively thin pieces, but fails where waste per square foot amounts to the saving and the cost of welding the

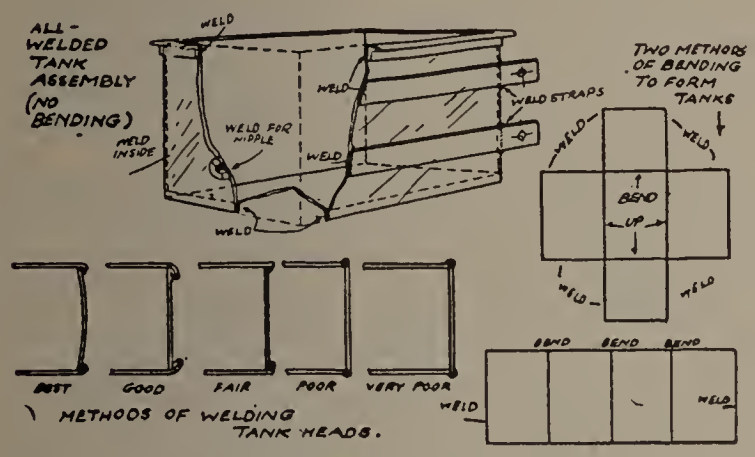


Fig. 2—Rectilinear Tanks

bottom seam. The better method is shown below where there is no waste and only one edge welded. Of course the bottom has to be welded in separately but this is easily done as shown in the larger rectangular tank illustrated by setting it in slightly and welding from the outside.

The larger rectangular illustration shows a method of welding which is by far the best for any but quantity production, in which bottom, sides and ends are separate pieces; the bottom being the inside dimensions wanted and the sides being as much greater as the thickness of material used, the ends fitting in between the sides against the bottom.

The top, if one is required, can be neatly fastened by welding an angle inside or out and then fastening top with bolts or hinges. If tightness is required, even gas or air tightness a shellacked cork gasket will give the required result; where the thickness of this tank is small the edges can be bent over to form this angle and the corners chipped off around or welded out square. The holes for fitting in the top, sides or bottom can be cut by the arc after the tank is completed and fittings set at the desired angle and welded without danger of warping the fitting out of place or of warping the sheet into which it is set. With arc welding the head can be put in dished or straight inside or outside and tacked in place. The weld can then be made with one or more heads continuously or in any sequence. Stay bolts if desired, can be welded in at any stage of the process that they are accessible without danger of pulling the head or sides out of shape.

Transformer Tanks*

Arc welding, with metallic and carbon electrodes, has been used extensively in the construction of transformer tanks at the Pittsfield Works of the General Electric Company for a number of years, and has proved to be a reliable and economical factor in the building of large and small tanks made of sheet steel varying in thickness from ⅛ of an inch to ⅝ of an inch.

Welding affords the most simple and effective means for making joints in steel plates that are capable of holding, without leaks, the warm oil which the tanks contain when in service. Riveted joints, which welding largely supersedes, could be made tight only after considerable caulking had been done on them. The use of welding has lowered the cost of tank making very materially and has reduced the amount of noise in the tank shops, thus making the tank makers' job more agreeable.

It is essential that the work be properly prepared before welding is begun. A thorough study must be given the job in hand before any attempt is made to weld.

This study must first be applied to the effect of heat on the parts being joined; second, to the accessibility of the parts to be welded; third, to the nature of the strains to which the weld will be subjected; fourth, to the machining and assembly of the parts; fifth, to the position in which the weld can best be made; and sixth, to what condition the weld is to be left when finished.

(1) The effect of heat is to produce expansions and contractions which must be provided for whenever possible, otherwise severe strains may be left in the plates and welds that will materially reduce their effective strength or leave the work in a warped and distorted condition.

(2) The parts to be welded should be made accessible, so that welding may be performed thoroughly and the work of the welder simplified.

(3) A study of the strains to which the work will be subjected is necessary in order to determine the kind of weld that should be used. Different kinds of welds will be required depending on whether the strain is a direct tension, bending, torsion, prying, compressive, or a composite one, and whether the strength must be great as in a main seam or small as in a caulking weld.

(4) The machining and assembly of parts must be such as to provide clean, proper, and sufficient contact surface for the welded-in portion and so arranged that a good and substantial joint will result.

(5) Whenever possible, the joint to be welded should be placed in the position that will be least arduous for the welder. Under this condition he will naturally do his best work. This position is usually in a horizontal plane. Vertical and overhead welding may be done and done well, but these positions are more difficult and tiresome for the operator.

(6) Usually the welt or raised portion of the weld is left on, but it is sometimes necessary to remove this and have a plane surface; for example, around the top of a tank for the placing of a hand, or if a tank is to have a special finish the entire raised portion of the weld may be removed. Under these conditions a light reinforcing weld may be made on the seam inside of the tank to compensate for the strength of the metal that has been removed.

When long butt seams are to be welded it is important, if the weld is to be made continuously and in one layer, to allow for a contraction of the joint as the weld progresses; and unless this is done, undue warping and excessive internal strains may result. The amount of the allowance for this contraction varies slightly with the speed at which the work is done and is usually about 1½ per cent of the length of the weld. That is, if the seam is ten feet long the space between the plates at the beginning of the weld would be ⅛ in., and at the end 1½ per cent of 10 ft. plus ⅛ in. or 1.9 in. Clamps are used to hold the plates apart the proper distance and these are gradually released as the weld approaches them. The welder watches the opening; if it closes too quickly, he hurries his welding; and if it does not close quickly enough, he waits for it.

These precautions need not be taken in the case of very short butt welds, lap welds, or in long welds between bases and shells of tanks. These welds are either too short to develop any serious strains or the parts have an opportunity for breathing that dissipates the strain over a wide area.

*By R. E. Wagner in the General Electric Review.

Locomotive Tender Tank

A departure from the customary riveted type of tender tank has been reported in the case of an Eastern railroad which built a tender tank entirely by electric arc welding.

The manner in which the sheets were welded to the tank angles is shown by Fig. 3. This is a satisfactory method as the welding can be done readily at reasonable cost and the strength of the joint is in excess of that usually obtained by the riveted type of construction. The side plates are butt-welded and the tank braces and splash plates

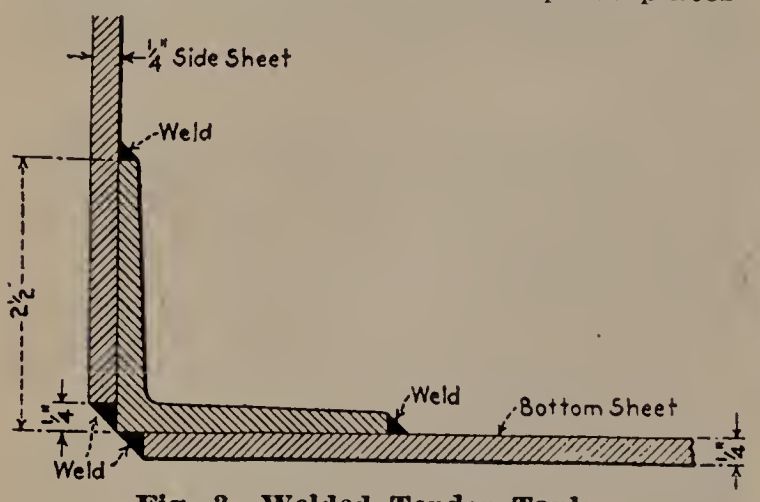


Fig. 3—Welded Tender Tank

are afterwards securly welded to the side sheets. The whole construction results in a water-tight tank of good appearance and great strength.

In assembling the various parts of the tank, approximately 1,200 linear feet of welding was done. The following tabulation shows the welding work in detail:

Butt-welded seams ¼" plate	95 ft.
8 Reinforcing tees, 3½x3½x⅜"	550 ft.
10 Tank angles, 2½x2½x$\frac{5}{16}$"	410 ft.
23 Side tees, 3½x3½x⅜"	120 ft.
Beading at coal side	25 ft.
Total linear feet of welding	1,200 ft.

The safety appliances and tank lugs are riveted to the sheet. The completed tank is 26 ft. long, 10 ft. wide and 5 ft. 2 in. high, having a capacity of 8,000 gallons of water and 12 tons of coal. It is supported on a cast steel underframe and is used with a Pacific type locomotive in passenger service.

WELDING A 5,000 BARREL OIL TANK

A recent report of the Committee for the electric welding of storage tanks of the American Welding Society makes the following recommendations for the construction of a 5,000 barrel tank, approximately 44 ft. in diameter and 25 ft. high. Where lap joints are used, it is recommended that the lap used be six times the thickness of the sheet.

Bottom

The committee suggests that the tank site be prepared in accordance with the present practice for the erection of riveted tanks, that the place where the tank is to rest be leveled and that a cushion of 1 inch or 2 inches of sand be provided on which to place the bottom.

Fig. 1, Plate I, is a drawing on a small scale showing the bottom of the tank in plan. There are two alternate methods of constructing the bottom.

Fig. 8, Plate II, shows the lap weld, and Fig. 11, Plate II, shows another method in which all plates are horizontal. Referring to Fig. 8, before the plates are brought to the field holes approximately 1" in diameter may be punched along one edge of the plate about 12" apart or these holes may be burned in the plates after they are delivered on the job. The edge of the plate with the holes in it, as shown in Fig. 8, Plate II, is laid on top of the other sheet and a full continuous weld is made as indicated on the drawing. In order to stiffen this weld the upper and lower plates are attached to each other by filling in the holes in the upper plate as shown.

The method shown in Fig. 11, Plate II, involves no preparation of the plates before they are brought to the work. The edges of the plates are laid with a gap between adjacent plates. This gap should be not less than one and a half times the thickness of the sheet and need not be over twice the thickness of the sheet. Under the edges of the sheet is laid a steel bar 1½ in. or 2 in. wide bridging the gap between the two plates. A weld between the plate and the bar at the bottom is made and a similar weld between the other plate and the bar at the bottom is next made and, third, the groove left by the first two welds is filled up level. This is indicated on the drawing by having the first two welds in heavier lines than the third weld.

Fig. 3, Plate I, shows the proposed method of welding the side of the tank onto the bottom plate. The outside angle is rolled to the proper diameter before being brought to the work. After the bottom is welded this is placed and welded into position. Next the bottom sheets which project beyond the angle may be cut off with an acetylene cutting torch or these plates may be properly cut before being sent to the job. The angle being placed and welded to the bottom definitely locates the position of the bottom edges of the first row of shell plates. These plates are placed in position by a derrick, then the bottom of the plate is clamped to the angle and a full continuous weld made between the bottom edge of the shell plate and the bottom and a further weld made between the upper edge of the angle and the outside of the shell plate as shown in Fig. 3, Plate I.

Fig. 7, Plate II, shows in greater detail the manner of welding the bottom of the tank to the first row of shell plates. After welding the first row of shell plates to the bottom is completed a temporary dam 6 in. to 8 in. high is constructed around the outside of the tank and water is run in to a height of from 4 to 6 in. This water will tend to float the tank and will detect any imperfections in the welding of the bottom by seeping through such a defect. These spots, if any, can then be repaired.

Shell Plates

Fig. 2, Plate I, shows on a small scale an elevation of the side of the tank. The details of construction of the shell of the tank are shown in Figs. 3, 4, 5, 6, 9 and 10, Plates I and II. The only difficulty anticipated in the construction of the shell of the tank is in holding the plates in place preparatory to welding. A derrick is provided for raising the shell plates in position and properly placing them.

Fig. 4, Plate II, shows a Z bar for supporting the sheet forming the second row of shell plates. A wedge for accurately adjusting the vertical position of this sheet is shown. Fig. 4, Plate II, section BB, shows a method of providing support for the end of the shell plate being erected adjacent to the shell plate on the same row already in place. These guides can be made of small pieces of plate ½-in. or ⅜-in. thick. The sketch can be made of small pieces of this plate. The guides can be knocked off and rewelded in a new plate or left in place as preferred.

Fig. 6, Plate II, shows a clamp with a pair of rollers which can be set over the edge of the sheet and draw the lower edge of the second row of shell plates and the upper edge of the lower row of shell plates into contact preparatory to being tacked into their position. After the plate is properly positioned and tacked in a number of places to hold it, the Z bars may be removed and the clamp slid along the plate in order to hold the edges of the plate in intimate contact while welding.

All the welds on the shell plates are lap welds in order to give additional rigidity and freedom from possible leaks.

Fig. 10, Plate II, shows the upper weld on this lap weld to be a full weld; the lower

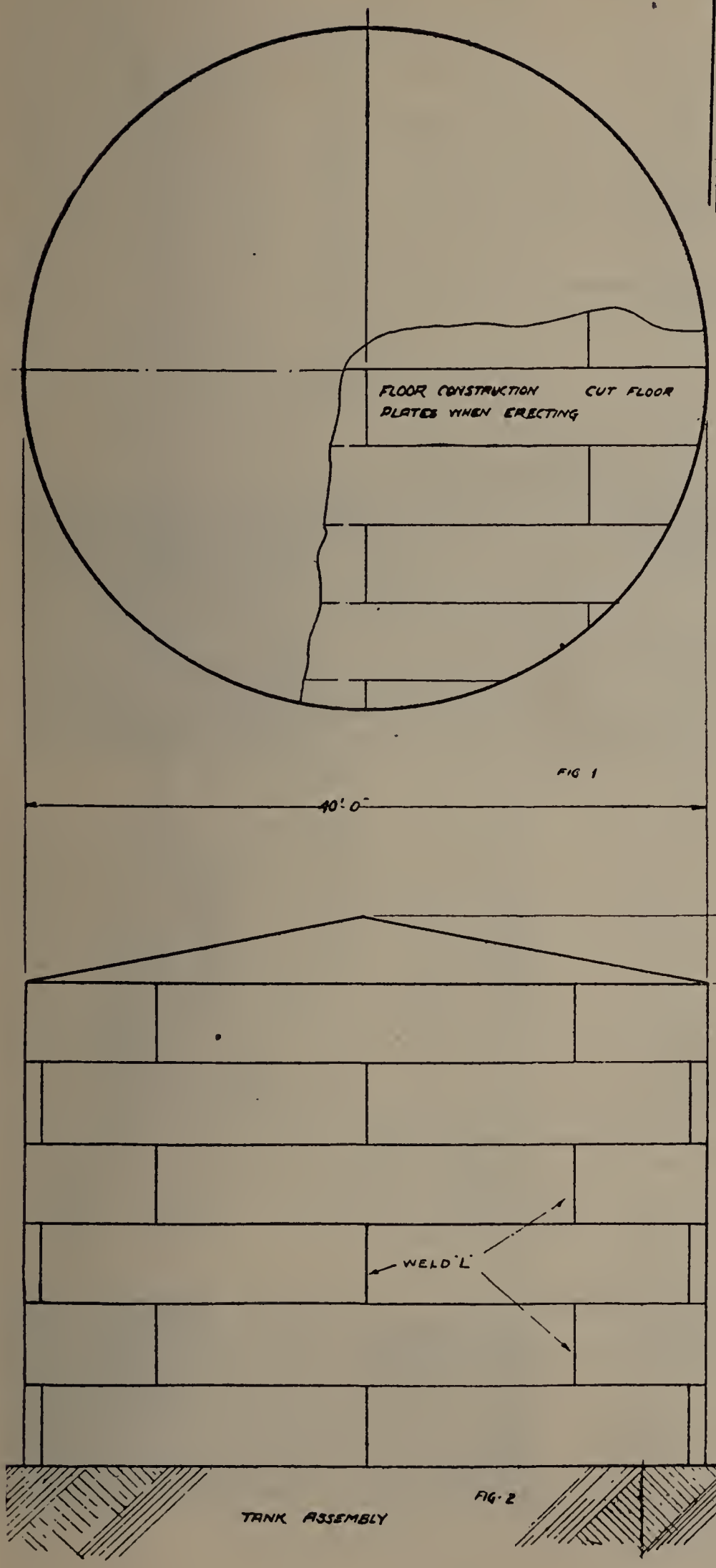


FIG 1

FIG. 2

TANK ASSEMBLY

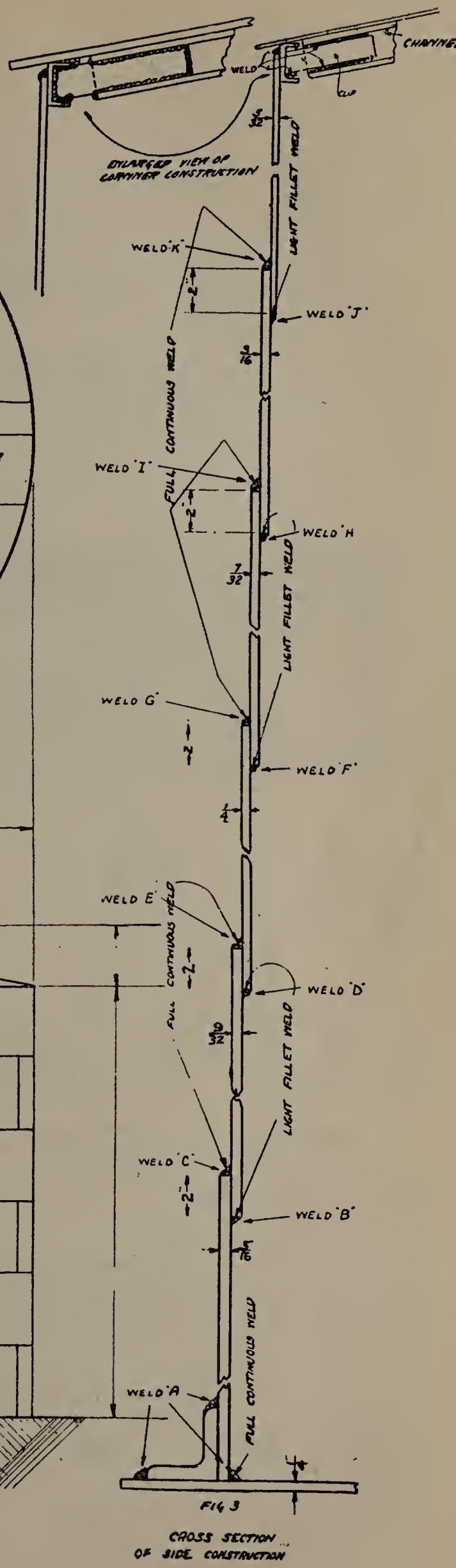
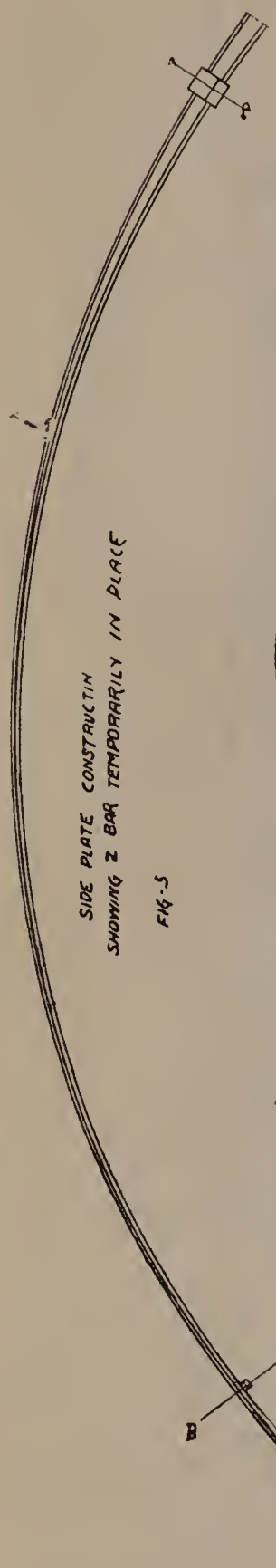


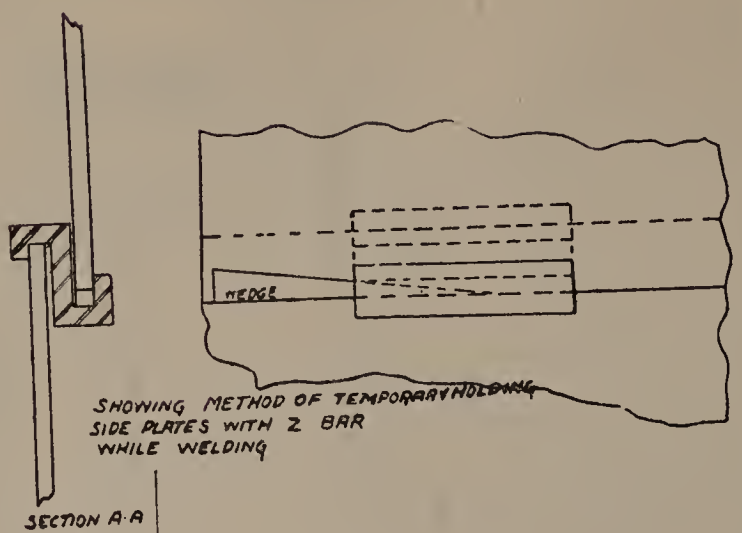
FIG 3

CROSS SECTION OF SIDE CONSTRUCTION

PLATE I.



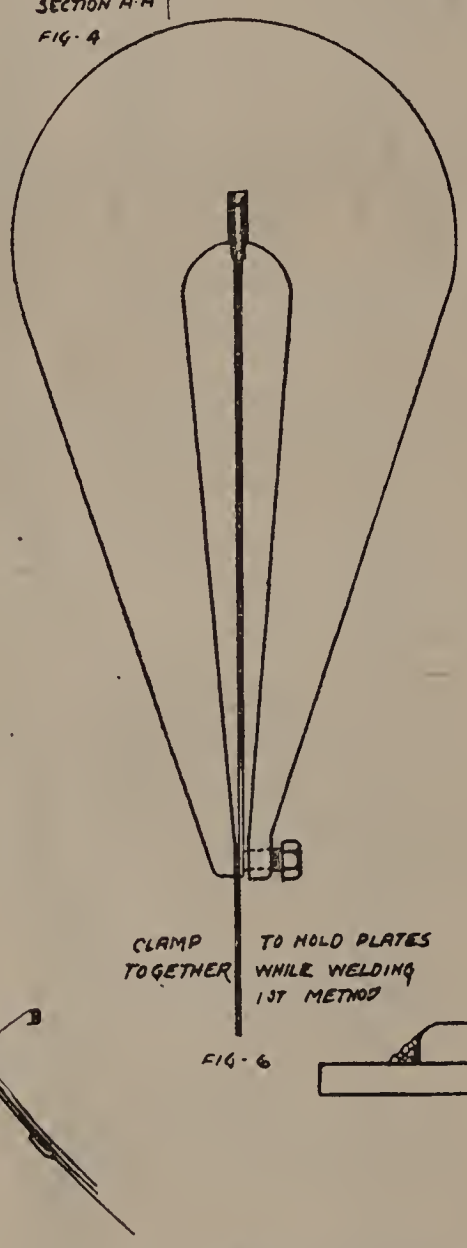
SIDE PLATE CONSTRUCTION
SHOWING Z BAR TEMPORARILY IN PLACE
FIG-5



SHOWING METHOD OF TEMPORARY HOLDING SIDE PLATES WITH Z BAR WHILE WELDING

SECTION A-A
FIG-4

FIG 4
SECTION B-B

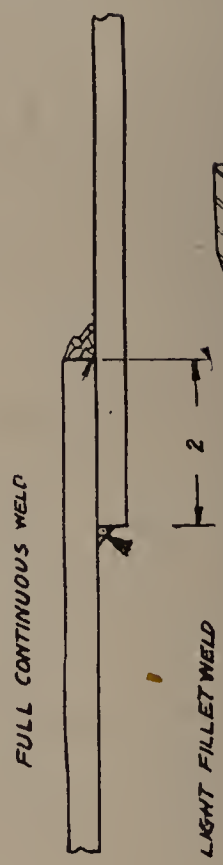


CLAMP TOGETHER TO HOLD PLATES WHILE WELDING 1ST METHOD

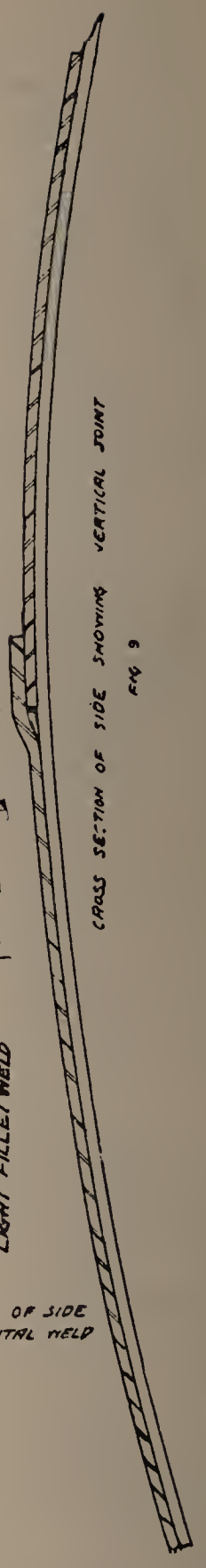
FIG-6

CROSS SECTION OF BOTTOM & SIDE CONSTRUCTION

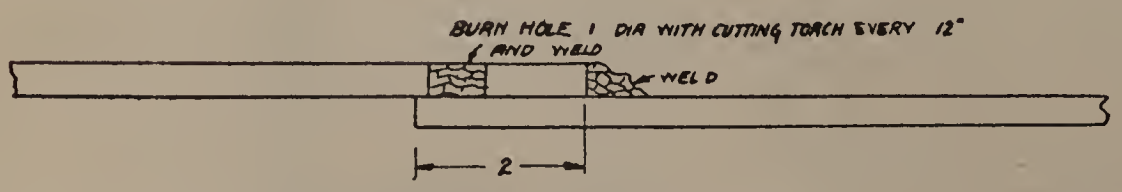
FIG-7



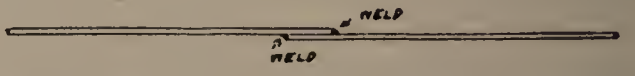
CROSS SECTION OF SIDE SHOWING HORIZONTAL WELD
FIG 10



CROSS SECTION OF SIDE SHOWING VERTICAL JOINT
FIG 9



CROSS SECTION OF BOTTOM CONSTRUCTION
FIG-8 METHOD #1



TOP SHEETS CUT IN SAME MANNER AS RIVET TYPE TOP
FIG-12

CROSS SECTION OF BOTTOM
FIG-11 METHOD #2

PLATE II.

weld, which is more difficult and therefore more expensive to make, is shown as a small single bead weld.

Roof

It is recommended that the same columns for supporting the roof be provided as are used in the present riveted tanks and that these columns be welded to the bottom in place of riveting and that any spacing bars between the columns be riveted. The present practice calls for roof plates cut into a trapezoidal shape in order to obtain a cone shaped roof without springing the plates. When such plates are provided they should be welded as shown in Fig 12, Plate II.

Experience has shown that it is possible to use rectangular sheets for forming the roof and that such plates when laid over the supporting roof members will form the desired cone shaped roof. It is, therefore recommended that rectangular sheets be used for the roof.

At the top of Fig. 3, Plate I, is shown the detail of the proposed method of joining the roof and top row of shell plates. The channel iron is welded in place on the top row of shell plates before the roof members are attached. A clip for each roof member is welded to the channel and each roof member is welded to these clips. These clips are provided to make it easy to attach the roof members to the channel in case of any irregularity in the outline of the tank on the top row of shell plates. After the roof plates are laid the channel and roof are welded to make a gas tight joint.

Welding Bottoms and Roofs on Mammoth Storage Tanks

Bottoms and roofs of oil storage tanks, having a capacity of 80,000 barrels, have been successfully welded by the electric arc process. The diameter of one of these tanks is 117 ft. The straight steel sheets used for the bottom are 18 ft. by 6 ft. by $\frac{3}{16}$-inch, weighing about 900 pounds each. Sketch sheets are made of the same stock, but vary in size and shape. Sheets are lapped about 1¼ inch, and then tacked to hold them in place as they are laid. One tack is placed on the long seam and one on the cross seam, then as many more tacks are put on as possible before the next sheet is in place. Tack welds are about an inch long and spaced at intervals of about 18 inches. After all the sheets are in place the tacking is finished in those portions where longer intervals have been left in the first course. It is necessary to provide a number of unskilled laborers for handling material and for guiding heavy weights to press the sheets together while the welder is handling the electrode. A considerable saving of money is made possible through welded construction, because the bottom can be laid directly on the ground. When riveted construction is used, it is necessary to erect cribbing so that the bottom is about 2 ft. above the ground.

When the tacking is completed an inspection is made for bad places where sheets were bent or would not come together by the ordinary means. They are forced together and tacked extra strong. An outside angle-iron ring is then tacked in place and the first shell ring hung on the angle. This shell ring serves the purpose of protecting the welder from the wind while he is welding the seams.

Welding can be started on the long seam at the center of the tank and carried out toward the outside angle iron. When the long seam is finished, the 6-ft. cross seams for that section are welded. Then the second long seam is welded and the second set of cross seams, and so on across the tank to the angle iron. There is not much danger of contraction strains being set up.

Tacking and welding on roof proceeds about the same as on the bottom, except that in bad weather the welder is apt to be troubled by wind and cold. Some protection can be obtained by using windshields which may be fastened together at right angles with two 2-inch by 18-inch by 4-ft. faces.

Tacking Plates for Bottom of 80,000 Barrel Tank.

Windshields Protect Both the Welder and the Arc.

GAS WELDED TANKS

STORAGE TANKS

The tendency in favor of the welded tank was at first confined to tanks of relatively small capacity—a natural result of human conservatism in cautiously feeling the way to ultimate development in new fields of endeavor. With the welded tank, the relatively tiny vessels that first engaged engineering attention are now completely over-shadowed by the larger construction of today. And, measured by the not remote future, the welded tanks we now regard as large are themselves but pygmies.

The tank shown in Fig. 4 is not an example of the largest welded tanks made today. There has been one tank fabricated of nearly four times this tank's capacity, and there is a standard line of tanks manufactured by a welding company in the South that exceeds the capacity of the tank shown by a thousand gallons. But the tank illustrated is presented as typical construction of its kind, and was selected because of certain interesting details connected with its fabrication.

The specifications called for a tank 10 feet in diameter by 38½ feet in length (approximate capacity 24,000 gallons), built of $\frac{3}{16}$-inch shells in the body and ¼-inch plate in

the heads. It will be noted that there were eight circumferential seams with the longitudinal seams arranged alternately, three of which are visible in the picture and four (not visible in the picture) being diametrically opposite. The heads are fabricated of five pieces joined by the two long and two short welds. The seams are all butt welds, built up on the outside to afford added strength. The sheets were chamfered at the joints to insure penetration of the flame and filling material. A flanged manhole, also made with the blowpipe is seen at the top center of the tank. The tank was tested to an internal pressure four times greater than any load it would be subjected to in service and all seams were oil tight.

One of the largest welded tanks on record was built for the storage of gasoline. This tank was 22 feet in diameter and 30 feet high. It was made of ¼-inch steel plates, joined at the seams by oxy-acetylene welding.

Fig. 4—Oxy-Acetylene Welded 24,000 Gallon Storage Tank

PRESSURE TANKS

The following recommendations for procedure in welding pressure tanks by the oxy-acetylene process have been made by experienced supervisors:—Have all plate edges beveled 45 degrees. When welding longitudinal seams, separate the edges at the end opposite to the starting point a distance equal to the thickness of the plate multiplied by the number of feet in the length of the seam. When welding circumferential seams, tack the parts together at half a dozen equidistant points and weld between the tacks. Weld circumferential seams only on the outside. Weld longitudinal seams on the outside if the stock is less than ¼" thick, and on both sides for high pressure containers of greater thickness, welding the inside seam first, and reinforcing about ten percent on each side. This should also be the maximum reinforcement for longitudinal seams welded on the outside only. Test every tank with hydrostatic pressure at least twice as great as the working pressure. Have each weld inspected for visible defects by a welding expert, and provide means for testing each welder's work at regular intervals.

After the weld is completed the weld should be stronger than the parent metal. The selection of the tank material and welding rod, the design of the weld, the welding procedure and the amount of reinforcement should be specified with this end in view. Additional safety can be given the structure by rolling the cylinder after the longitudinal seam has been finished. This is because the flat spots left at the ends in the first rolling will tend to assume a circular shape under pressure, putting a bending stress directly on the weld, whereas if the cylinder is rolled after welding the internal pressure in service will put a uniform tensile stress on the entire shell. Where thick plates are used for tanks of relatively small diameters it may also be advisable to heat the weld and the metal for a few inches on each side of it, to a dull red (900 deg. F) for the purpose of relieving the strains set up by welding. The necessity for this precaution decreases as the tensile strength of the parent metal decreases.

In many important instances a large measure of the success of gas welding tanks has been due to careful selection of base metal and welding rods. Mr. S. W. Miller finds that the best welds can be made in low tensile strength plate, containing a maximum of .15 per cent carbon, .60 per cent manganese, .05 per cent sulphur, and .04 per cent phosphorus, having a maximum tensile strength of 50,000 lbs. and a yield point at least half the tensile strength. It should also be free from non-metallic impurities and properly annealed. As to the welding rod, the same author states that the low carbon material ordinarily employed does not appear to be strong enough to allow for welds that are somewhat imperfect and advocates instead a rod containing .15 per cent to .25 per cent carbon, .50 per cent to .80 per cent manganese, .045 per cent sulphur, .04 per cent phosphorus and 3.25 per cent to 3.75 per cent nickel.

Production Welding of Pressure Tanks*

Pressure containers subjected to varying conditions of pressure change shape slightly unless the shells are made truly cylindrical. This weaving or breathing action if excessive may eventually cause cracks to develop, and it is of importance to minimize all movements of this sort, especially in or adjacent to welds. The shell should be rolled truly cylindrical and the edges bent to conform to the circle so that when joined and welded there is no appreciable flat section. If the ends of the sheet are not fully curved after rolling, the section will not be truly cylindrical and when the shell is subjected to internal pressure the flattened part changes shape, thereby setting up a bending stress in the weld and metal adjacent. When the pressure is relieved the parts tend to straighten again.

Too much stress can hardly be laid on the importance of sound mechanical practice on all work leading up to welding. True bevels, circular shapes, straight edges, convenient work supports and work-handling appliances contribute much to the success of welding.

**From a paper read by Fred E. Rogers before the American Welding Society.*

Preparing for Welding

Several methods are employed for beveling the edges of joints preparatory to welding, and while some are more efficient than others no absolute rule can be stated as the best to follow. Edges of flat plates may be beveled at low cost on a plate beveling planer before rolling them to cylindrical shape. Thus true beveled edges will be produced in the length and girth seams.

Lap welded pipe used for shells may be cut off and beveled in a cutting-off machine systematically and at low cost.

The flanged heads may also be beveled by chucking in a lathe, turning the edge to an angle while cutting the flange to length.

But in some cases owing to lack of equipment the ends of the shells are not beveled, and then the beveled flange of the head is tacked to the end of the shell ⅛ to $\frac{3}{16}$-inch apart at the bottom of the groove depending on the thickness. Again, neither the shells nor the flange are beveled in which case more space between must be allowed when tacking. In other words, when preparation is incomplete it is provided for by allowing more space of filling material. The torch is used to break down the sharp corners immediately at the beginning of the welding, and the molten metal sloughs down and thus is created a groove for filling in.

Heading Large and Small Tanks

Small diameter lap-welded pipe may be headed with flat discs set inside the pipe and welded at the edges, or the discs may be cut to the same size as external diameter of the pipe and welded to the end. Either form of head is objectionable from the standpoint of good design, but the welds can be made so much stronger than required to withstand the pressure in pipes of 8 inches diameter or less that there is no serious objection to such construction. The most

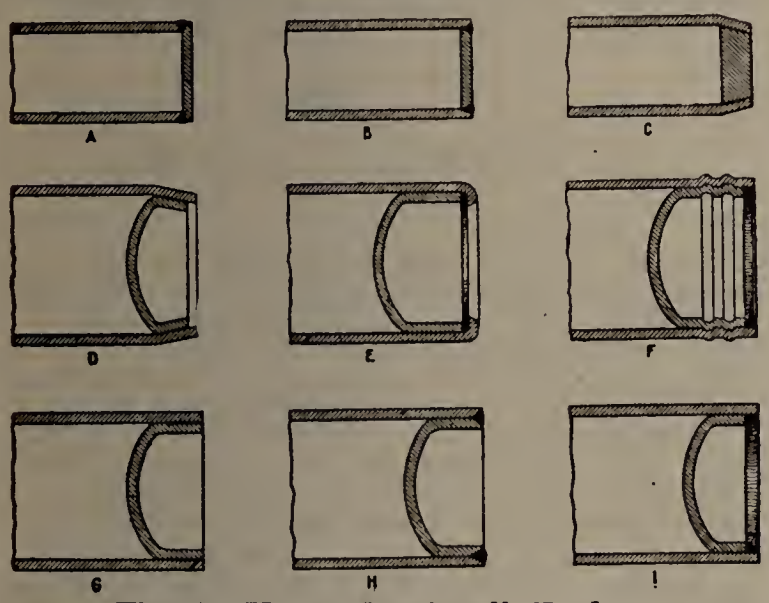


Fig. 5—Heads for Small Tanks

elegant method, however, is to provide dished heads.

A cylinder with flat or dished heads subjected to internal pressure develops the severest bending stresses at the junction of the head and cylinder part. It is important, therefore, to locate the weld outside this zone. Fortunately it can be easily accomplished by flanging the head and welding to the shell at a distance of two or three inches from the angle. The bending stress is thereby located in unwelded metal.

In some cases the flange is set inside the shell and welded in the outside corner. Large shells treated in this manner may be corner welded inside also. Another practice is setting the flanged head inside the shell, turning the end of the shell over the head and welding the edge. This makes a very strong job. In fact, it is much stronger than necessary, and is in reality poor practice judged from the standpoint of engineering efficiency.

When dished heads are applied to receivers and welded with the oxy-acetylene torch the convex part of the heads is turned outward at both ends, of course, thereby giving the maximum capacity possible. If, however, the heads are welded in at the forge it is necessary to turn the convex sides of both heads in so that the ends may be welded on the anvil. With riveted construc-

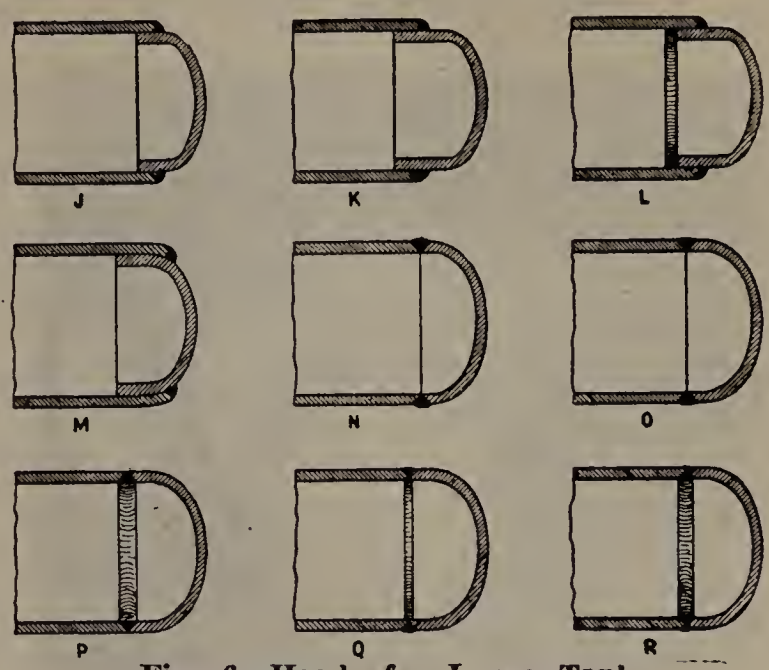


Fig. 6—Heads for Large Tanks

tion the convex side of one head must be turned in to "hold on" and rivet the seam.

Designs of heads for small tanks are shown in Fig. 5, and for large tanks in Fig. 6; a complete collection of tank seam designs, including a few additional head designs will be found in the section devoted to Charts and Tables. Fig. 7 shows the design and position of weld commonly used for assembling brine coolers.

Rigid and Non-Rigid Systems of Welding

When welding the longitudinal seam in a rolled steel cylinder single handed it is

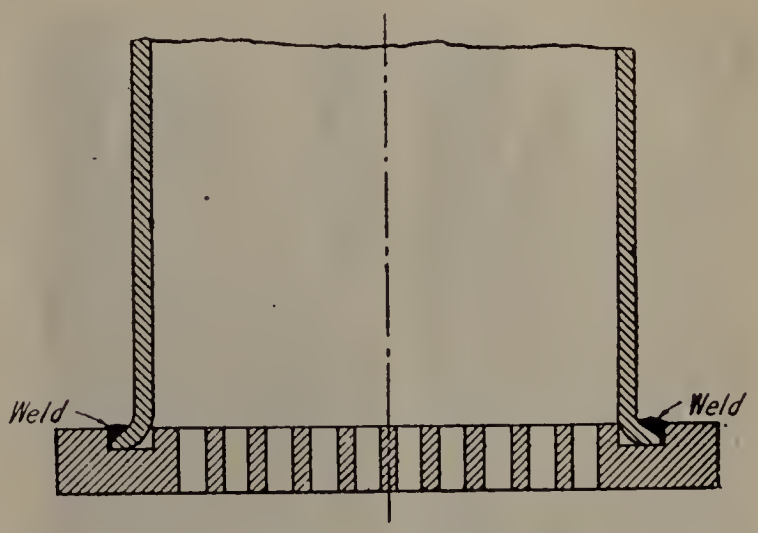


Fig. 7—Brine Cooler Assembly

necessary to start welding at one end of the seam with the sides out of parallel a variable amount depending on the thickness of the metal, speed of welding and equipment provided for holding the parts in proper relation. A common rule for the thinner shell plates is to set the edges apart about ¼-inch per foot of length. The seam in a shell 8 feet long, for instance, would be tacked together at one end, while the gap at the other is held to about 2 inches. A somewhat greater allowance is desirable for plates ⅜-inch thick and more. Some concerns give considerable more allowance on even thinner sections running as high as six per cent.

This is an example of the non-rigid system of welding. The contraction of the cooling weld draws the edges of the plates together as the weld proceeds, and if the allowance has been correctly made and the welding has proceeded at a uniform rate

the edges will be practically parallel when the end of the seam is reached.

If the attempt were made to tack the edges of a rolled sheet and to weld the seam with parallel edges, the result would be a peaked seam, the cross section looking more like a pear than a circle.

An example of the rigid system of welding is afforded when a flanged head is welded to the end of a pipe or cylinder.

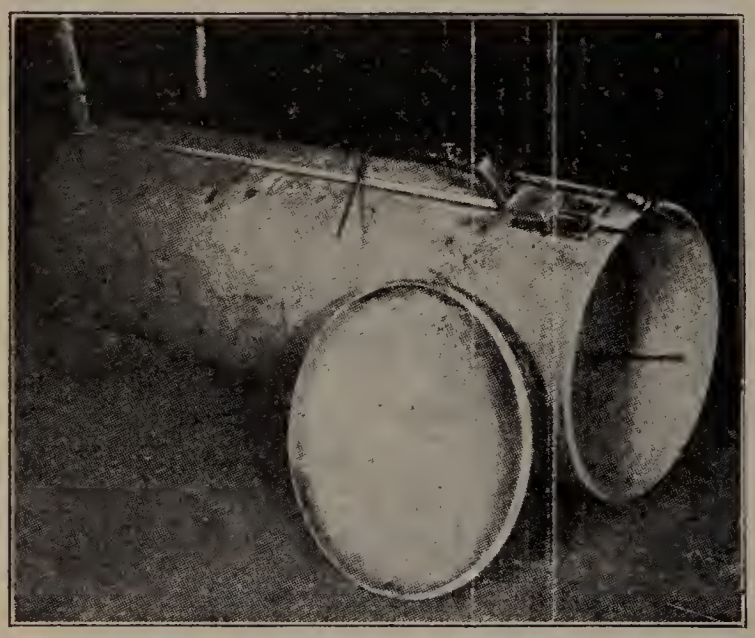
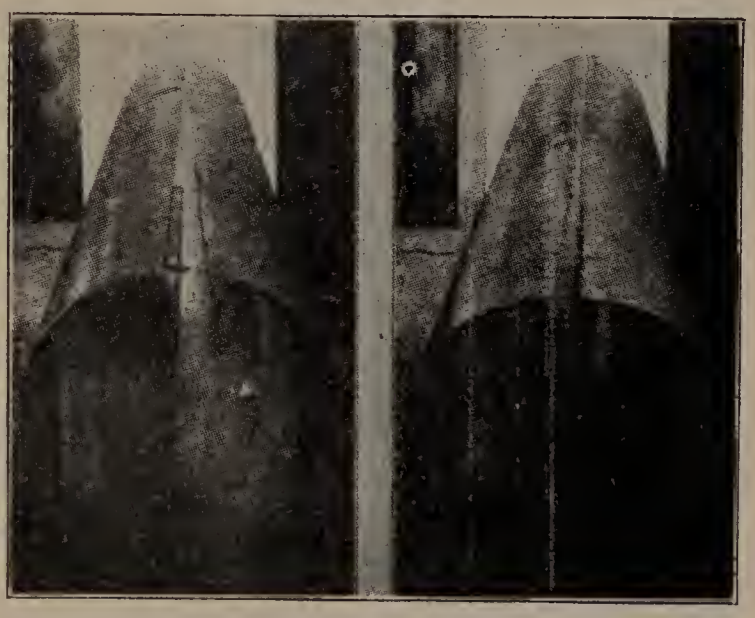


Fig. 8—H-Block Used to Control Contraction

The practice is to tack the flange at four or more points and to start welding at one of the tacks, using a wedge ahead of the weld to prevent contraction of the cooling weld metal drawing the parts together faster than desired. When the welding has proceeded half way around or somewhat more the wedge is dispensed with and the weld finished without other support than the tacked and welded portions. In this case the strain set up by the contracting weld cannot seriously distort the joint and



Figs. 9 & 10—Screw Jack Used to Control Contraction

no allowance practically need be made for the contraction of the cooling weld. What the strains are we can only guess. The fact that a circumferential weld is theoretically two times as strong as a longitudinal weld of equal thickness and quality, however, makes the question of internal stress of little importance in girth seams.

Controlling Contraction

Blocks having a cross section like the letter H are used ahead of the weld to prevent the seam closing too rapidly. An H-block with broad lips (See Fig. 8) permits the use of wedges between the lips and shell to keep the edges from getting "wapper-jawed." Alternative practice is to use a jack in the open end of the shell and to ease it off as the weld proceeds. This scheme is illustrated in Figs. 9 and 10. Finally the edges close together at the termination of the weld.

More skill is required in welding longitudinal seams of pressure containers than on any other work done by the oxy-acetylene torch welder probably. The welder must secure thorough penetration and build up the weld to secure the maximum strength, while at the same time working the wedges to keep the edges true and the contraction proceeding evenly to the end so that when the weld is finished he shall have a straight seam and a truly cylindrical shell.

Welding Pipes to Tanks

When a pipe nipple is set in the side of a header the job must be handled in such a manner as will insure being upright or square with the pipe when the work is cold. If only one nipple is set the job is comparatively simple as the operator need not take into consideration the accumulative contraction effect of several welds. When a weld is made in the side of a pipe the tendency is to contract that side and bend the pipe.

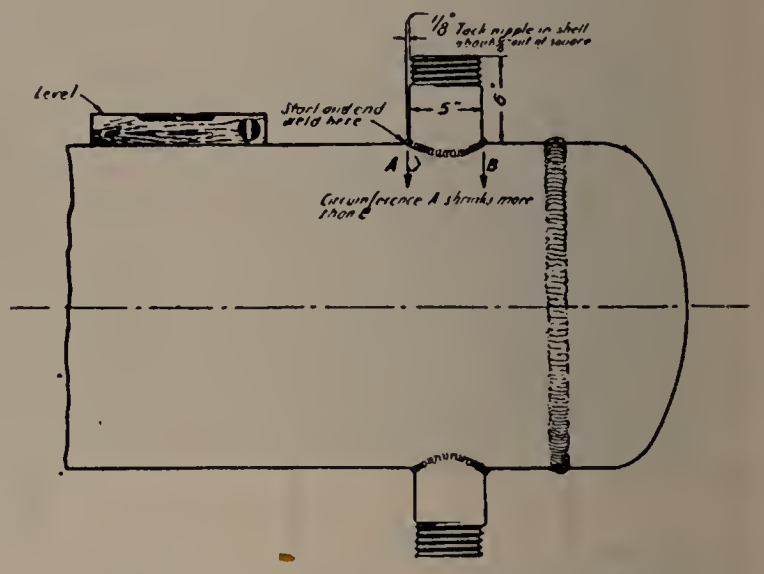


Fig. 11—Welding Pipes to Tanks

This is due to the expansion of the hot metal which causes upsetting as the cold metal surrounding it prevents full expansion. The subsequent contraction shortens the fibres on that side of the pipe and throws it out of straight line. However, the effect of the upsetting action is comparatively slight, and when only one nipple is set it will be imperceptible, especially if the pipe is of large diameter and comparatively short.

When close to a head or flange the operator may then set the nipple out of plumb an amount depending on the length and diameter. A 5-inch nipple six or seven inches long projecting from the side of a pipe 16 inches diameter close to a head or flange should be thrown out of plumb about ⅛-inch, lengthwise of the pipe, and welding should start on the low side, or in the larger angle. (See Fig. 11.) It should continue around and finish at the same point. The effect of the expansion and contraction will be sufficient generally to square up the nipple. If the normal contraction effect is not sufficient it can be increased by again playing the torch flame around the base and cooling suddenly with wet waste.

The tendency to upright a nipple set and welded in the manner described may not be quite clear. It is attributed to the shortening of the circumferential fibers due to the repeated heating of the metal at the nipple base at the start and finish of welding. On the opposite side the metal is made hot but once, and hence the shortening of the circumference is less than where the metal is made hot twice. Moreover, a flange or head resists contraction stress and tends to hold

the metal at the base of a nipple close by rigidly in place. By reheating and sudden cooling the effect is accentuated. In fact, a welder experienced in the trick can actually produce a distinct wrinkle of depression in a shell.

Suppose that eight or ten 2-inch nipples are to be set in the side of an 8-inch pipe, ten feet long. Here is a condition in which the cumulative effect of contraction and bending is perceptible, and it has to be taken into account. The simplest plan is to use an 8-inch pipe bent so that a straight edge will show a drop of say ½-inch in the center. The nipples are welded in and the contraction produced by the upsetting action and subsequent cooling shortens the long side of the pipe, an amount that will depend on its length, diameter and number of welds on the nipples. The shortening effect should, of course, be just enough to make it straight. Small diameter headers of considerable length may be straightened after welding in the nipples by heating and bending the section between the nipples.

Welding a 5,000 Barrel Oil Storage Tank

A recent report of the Committee for the Oxy-Acetylene Welding of Storage Tanks of the American Welding Society makes the following recommendations for the construction of a 5,000 barrel oil storage tank:

General Principles. In oxy-acetylene welding it has been established that sheet metal and plates are best joined by a butt-weld, which is therefore assumed as the basis for building up the proposed tank.

In joining sheets or plates by oxy-acetylene welding, a smooth finish is obtained by having the sheets or plates separated an adequate amount at the end of the seam toward which the welding is progressing. This method of lining up the work is followed in the specification.

All plates should be squared, cut to size and beveled before welding.

Bottom Construction. The first step in the construction of the tank will be to lay out the bottom curb, welding section to section until the curb has been completed. Then lay out the bottom plates, tack same to the curb and to each other, beginning from the circumference and working toward the center of the tank. The layout of the bottom sheets is shown in Plate III.

The next step will be to weld the side sheets of the first course to the upper edge of the curb and end-to-end to each other as shown. In order to control the expansion of the metal it has been found much the best practice to hold one corner of the plate open in accordance with the usual practice of handling sheet metal. This gives better results than when the sheet is tacked to the curb and then filled in.

In welding a plate to the end of one which is almost welded into position, it is found best to leave an opening at the upper corners, starting the welding from the lower corners, because then the contraction of the weld is tending to pull the unattached place into proper alignment, whereas if the welding is started at the top, leaving the bottom end open, the weight of the plate tends to force the contraction too much.

The next step is to weld the bottom sheets to the curb, then to each other, changing the welding position after filling in between any two sets of tacking welds. If there is any distortion of the tank it can be controlled by extending beams across the top of the first course, so wedging these beams as to establish a true circle. If the plates have been correctly prepared the circumference of the curb and the top of the first course must be correct and it is only a matter of bracing to start the sides of the tank correctly and to tack the bottom in place without effect on the sides of the tank.

The bottom should now be tested for tightness. On the first tank it is proposed that at least two inches of kerosene should be used for this purpose.

Side Construction. The second course is to be welded to the first course in the same manner as the first course of plates was welded to the curb. When the plates have been welded together so as to establish a complete ring, except for the last seam, the necessary spread of seam can be provided by putting block and tackle on the upper corners of the two meeting plates and spreading same by bending outward. As welding progresses the tackle must be eased off, but no difficulty has been experienced in thus handling the last vertical weld in actual practice.

The remaining courses will be added in the same procedure until the side of the tank is complete.

Roof Supports. In this tank the roof is supported by beams from a central frame made up of angle iron sections bolted together and having the outer ends of the beams attached to clips welded to the side of the tank.

The central support should be quite valuable during the construction of the tank as a support for beams to hold the side sheets.

The roof support must be strong enough to carry twelve inches of snow.

Roof. The top plates should be tacked together and tacked to the upper edge of the side sheets. The weld at the corner of the side sheets should then be made. The procedure for welding the remainder of the roof will be the same as for filling in between the tacks and the bottom.

Testing. The tank sides should be tested by filling the tank with water and all welds will be hammered with wooden mallets. As water is quite a bit heavier than oil this will give a good factor of safety test.

The top should be tested by chalking the under surfaces and painting kerosene on the lower surfaces, or the tank can be put under air pressure and the top seams tested with soapy water.

Fittings. All fittings should be welded in place. The sump may be welded in when the bottom is being welded and would entail no difficulties. The side manhole may be welded in place after the sheet is welded to the curb. The top manhole may be similarly handled, as may the gauge hatch and gas vent.

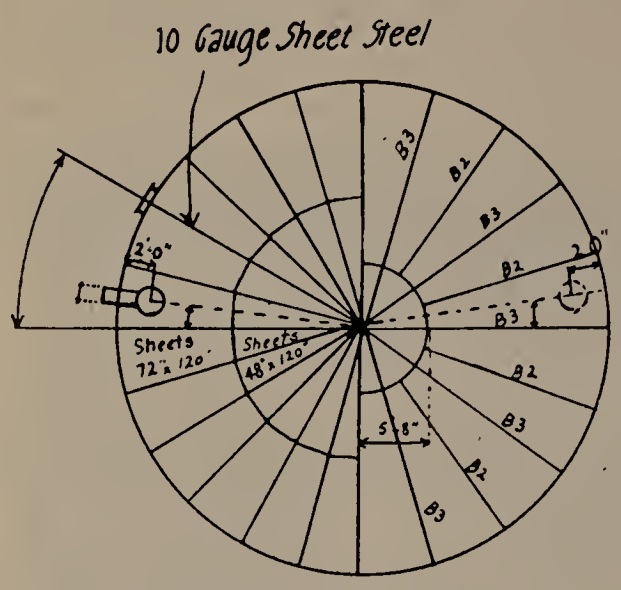
The ladders should be made by welding small pipe rungs into pipe of larger diameter; then the inner and outer ladders suspended as shown. This suspension is made by cutting holes through the side sheets, putting pipe through the holes then welding the pipe to the side sheets. The ladders shall be welded to the suspension pieces.

WELDING SMALL TANKS

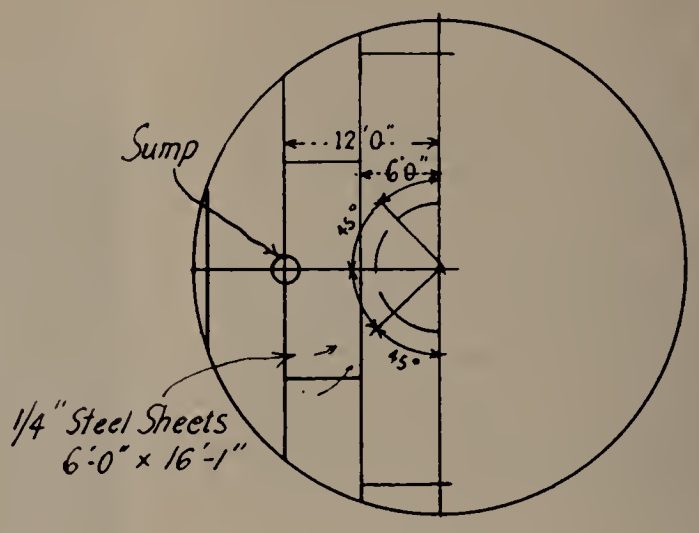
Preparation of Material for Welding

The kind, thickness and size of the sheets to be used will be determined by the purpose, capacity and design of the tank to be built. Under some conditions the thickness is prescribed by insurance or other regulations, while in some cities the fire laws govern the construction of tanks used as containers for inflammable or explosive liquids. Galvanized sheet is preferable for some purposes and peculiar conditions of placement will sometimes recommend the use of extra heavy sheet. The builder must carefully consider all the requirements demanded of the welded tank when planning its construction and selecting the material from which the tank is to be made.

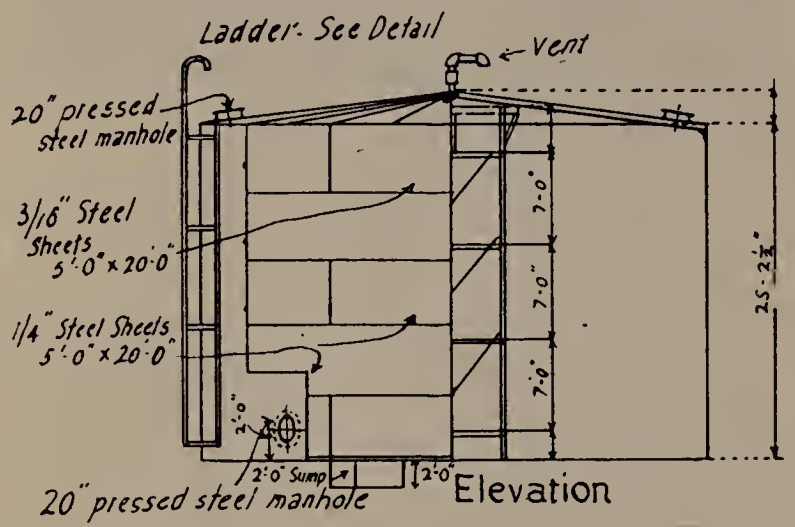
The selection of suitable sheet is worthy of very careful consideration because if this is neglected good tanks can hardly be produced even if the best fabricating methods are employed. Standard open-hearth steel tank plate is recommended by the Underwriters Laboratories, Inc., for the shell and heads of above ground inflammable liquid storage tanks; $\frac{3}{16}$-in. thick for diameters from 48 to 72 in. and ¼ in. thick for diameters from 73 to 132 in. The thickness of



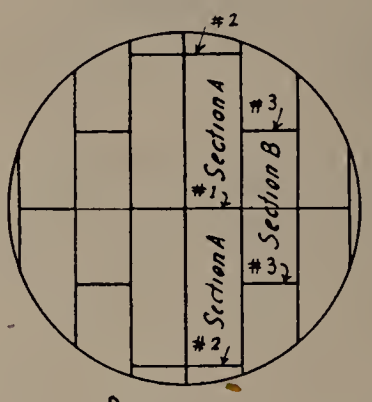
Half Plan of Top Half Plan of Framing



Half Plan of Bottom

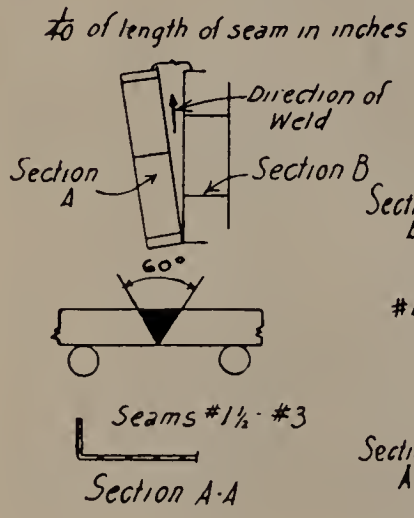


Elevation

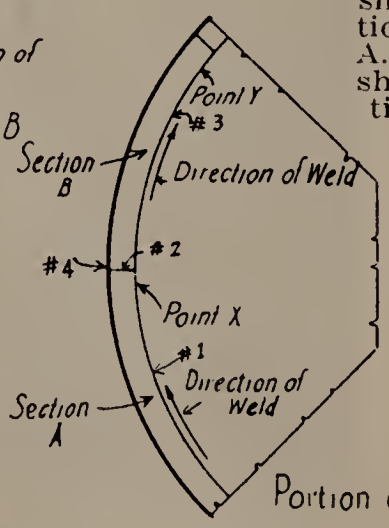


Bottom

Portion of Top



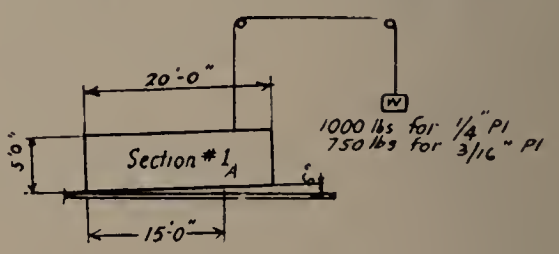
Section A-A



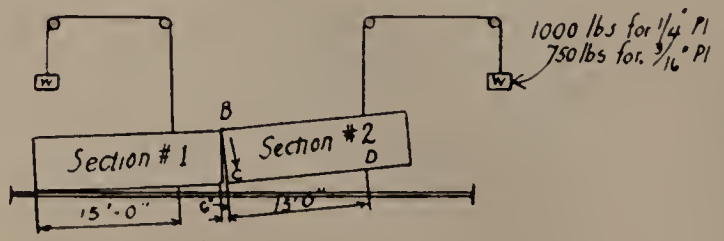
Portion of Bottom

WELDING PROCEDURE

Place plate section No. 1 in position shown in sketch X and weld in the direction indicated by the arrow to point marked A. Place plate section No. 2 in position shown in sketch Y and weld in the direction indicated by arrow from point B to point C, then continue weld from point A to point B. When point B is reached, add another section as shown in sketch Y and proceed as before. When ring is completed, weld as shown in sketch Z. Tack weld every 6 inches. Begin at the center and weld in the directions indicated by arrows in sketch Z.



Sketch X



Sketch Y

Sketch Z

metal required for underground storage tanks will be influenced by the conditions of the ground in which the tank is to be installed, but the following table, also furnished by the Underwriters, gives the minimum thickness of metal for various diameters and should prove a valuable guide in most instances:

Nominal Tank Capacity Gallons	Tanks for Installation Inside of the Fire Limits, of a City or for Installation Outside of Fire Limits, but Within 10 Feet of a Building	Tanks for Installation Outside of the Fire Limits of a City and Not Within 10 Feet of a Building
1-30	14 U. S. Gauge	18 U. S. Gauge
31-350	14 U. S. Gauge	16 U. S. Gauge
351-560	14 U. S. Gauge	14 U. S. Gauge

Tables containing the capacities of cylindrical and rectangular tanks of various sizes are to be found in any good mechanical handbook. Extracts from these are reprinted in the "Charts and Tables" Section for round tanks of not more than 500 gallons capacity.

If the capacity of a tank is prescribed, to obtain the proper dimensions first decide on a convenient height. Then to obtain the corresponding diameter multiply the given capacity in gallons by .1337 to determine the same capacity in cubic feet. (One gallon equals .1337 cu. ft. or 1 cu. ft. equals 7.48 gals.) Dividing this figure by the height or length gives the area of the bottom. Any mechanical handbook contains tables of the circumferences and areas of circles. From these can be obtained the circumference and the diameter of the (circle) bottom of the tank when the area is known.

If it is more convenient to assume the circumference or diameter of the bottom the same process will give the required height. Should the dimensions be given and the capacity be required determine the area of the bottom from the tables, multiply it by the height or length and divide the result by .1337. The result will be the capacity in gallons.

To find the size of a rectangular tank of given capacity assume any two suitable dimensions, the length and width or the height and length or width. The product of these divided by the capacity in cubic feet will give the third dimension. If the capacity is given in gallons, reduce this to cubic feet by using the factor .1337.

Reduced to formulae these calculations may be stated thus:

For Round Tanks:

A—Area of Bottom.
C—Capacity
D—Diameter of Bottom
H—Height or Length

$$D = \frac{C \times .1337}{H}$$

$$H = \frac{C \times .1337}{A}$$

$$C = H \times A \times .1337$$

For Rectangular Tanks

C—Capacity
H—Height
W—Width
L—Length

$$C = H \times W \times L \times .1337$$

$$H = \frac{W \times L \times .1337}{C}$$

$$W = \frac{H \times L .1337}{C}$$

$$L = \frac{H \times W \times .1337}{C}$$

For general purposes the thickness of the shell of a round tank may be calculated by the formula $\frac{P \times D}{2\,T}$ in which; P equals the pressure of the contents on the bottom of the tank in pounds per square inch, D equals the diameter of the tank in inches and T equals the maximum allowable working stress of the material in pounds per square inch, which is taken for use here to be 8,000 lbs. per square inch. This latter figure, of course, represents the tensile strength of the sheet.

The weight of a liquid confined in a tank will exert a horizontal pressure on the sides and tend to burst the shell vertically. Although the pressure will depend on the kind of liquid, the weight of water can be conveniently used for all general purposes. A column of water 2 3/10 ft. high and 1 in. square weighs 1 lb. The quantity P in the above formula is, therefore, equal to the height of the proposed tank in feet divided by 2.3.

To illustrate the use of the formula suppose it is desired to determine the thickness of sheet required for a 500-gal. open-top tank 4 ft. high and 4 ft. 8 in. in diameter.

$$1 = \frac{P \times D}{2\,T}$$

$$= \frac{(4 \div 2.3) \times 56}{2 \times 8000}$$

$$t = \frac{1.74 \times 56}{16{,}000}$$

$$= \frac{97.44}{8000}$$

$$= .0608 \text{ in. or 16 gauge}$$

This is lighter sheet than prescribed by the Underwriters because they specify slightly heavier material for inflammable liquids.

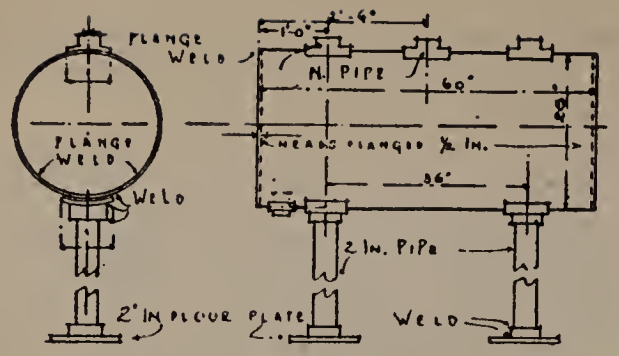
Unless material is on hand a careful estimate of what is required for a tank of given dimensions is well worth while, because much material can be wasted if sheets of a size that are not adapted to the tank dimensions are used. Stock sizes, of course, are most economical and the largest size usable is best as it requires the fewest seams.

When material is bought from a mill specified sizes can be obtained, but unless a quantity of tanks is to be built, material is usually obtained from local stocks where frequently exact sizes cannot be procured. Although this may prove an inconvenience it offers no real obstacles to the builder of welded tanks because odd-sized sheets can be fabricated easily and economically with the oxy-acetylene process.

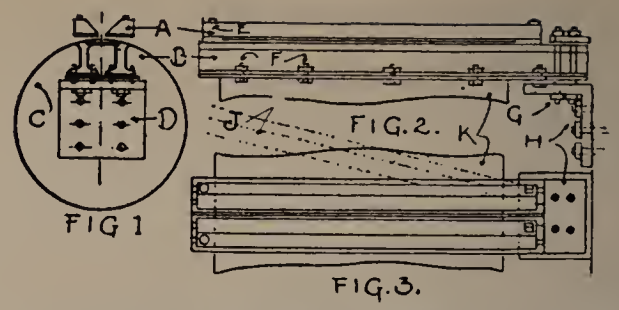
The shell sheet or sheets for round tanks should, of course, be the same length as the circumference. The end sheets may be the same size, in shortest dimension as the diameter or slightly larger if the edge is to be flanged. Ends of tanks may be made from narrow sheets by welding segments outside of the central section.

Dimensions of a rectangular tank will also determine accurately the proper material sizes. If the sides of such a tank are to be formed by bent sheets the bending process will not appreciably affect the dimensions of the sheet of the thicknesses considered in this article.

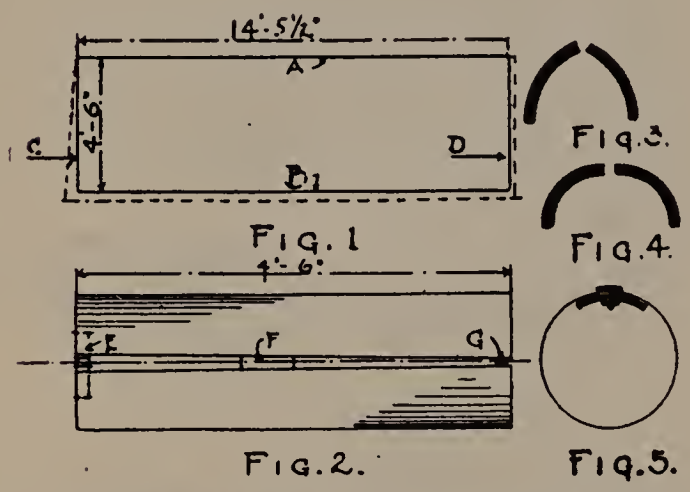
Methods for forming and shaping sheets are necessarily dependent upon the equipment available. Shops having access to presses and rolls can, of course, accomplish this phase of tank construction to the best advantage. If quantity production is to be carried on the usual sheet metal shop equipment, including shears, rolls, presses and throatless shears, for round and curved sections, are almost essential. In some localities it is possible to purchase sheets formed to



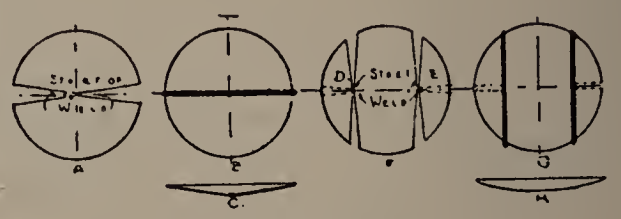
All Welded Fuel Oil Tank.
For use with domestic oil heating appliances Capacity, 150 gallons. 14 gauge blue annealed sheet. Note: Welded pipe standard and saddles



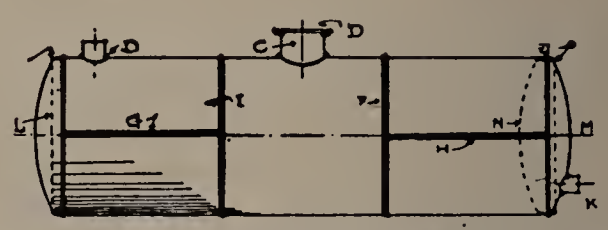
Jig for Welding Light Sheets.
Fig. 1. End view A. jaws. B. old rails. C. shell. D. bracket bolted to wall or column.
Fig. 2. Longitudinal section. E. pin holding end of jaw to place. G. bracket.
Fig. 3. Plan. J. open position of jaws K. shelf.



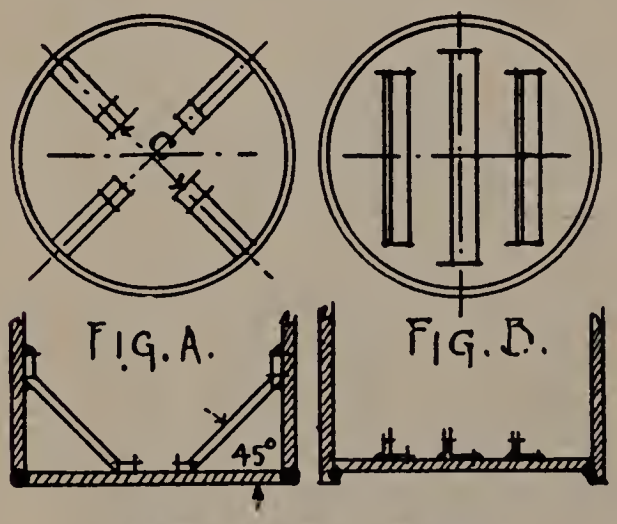
Preparation of Material for a Round 500 Gal. Open Top Tank.
Fig. 1. Layout shell so that edges A., B., C. and D. will be square and true.
Fig. 2. The shell rolled and ready to be welded. E., Clamp. F., Wedge G., tack weld. The weld is started at G
Fig. 3. Possible shape of the shell edges should be pounded into the shape shown in Fig. 4, about ⅛ in. below the true circle before welding.
Fig. 5. End view of shell showing clamp in position.



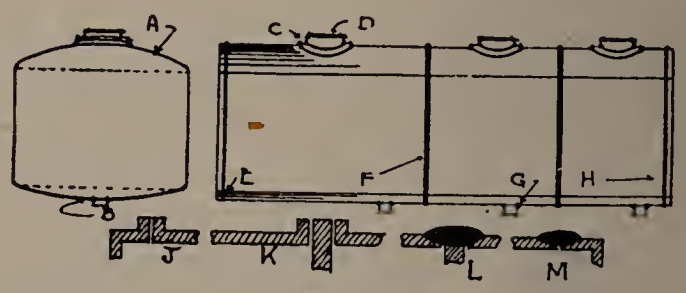
Built Up Tank Ends.
A and B containing two welded sections F and G containing three or five welded sections C and H show the shape of the ends after welding—accomplished by spacing the pieces before welding as shown in A and F.



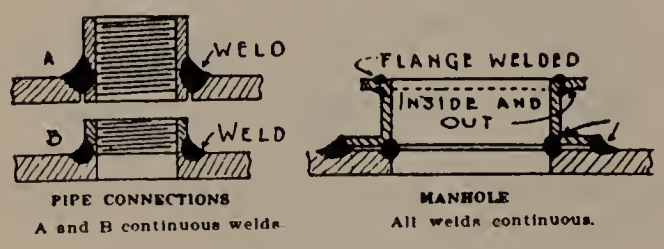
Sketch for an Oxy-Acetylene Welded Horizontal Oil Storage Tank.
A., end of shell. K., welded fitting C., manhole. E. and F., circumferential joints. G and H., longitudinal joints. N. end may be dished.

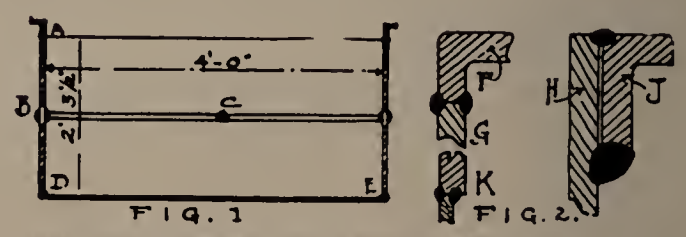


Bracing for Bottoms of Open Top Tanks.
Fig. A. Band iron tack welded to side and bottom C approx. ¼ the diam. Fig. B. Angle iron tack welded to bottom.



Truck Tanks
All welded construction. C. and D., Manholes. G., Fittings. E., F. and H., Welded Joints. J and M., Detail of End Joints. K. and L., Detail of Inside Joints at F. No filler rod is used with this type of joint. Note formed bottom. Top and sides are formed as one piece.





Reinforcing or Stiffening for the Sides of a Rectangular Tank.
Fig 1 A., angle iron tack welded to top edge. B., tie rod welded inside and out. C., welded joint in center of tie rod. D. and E., butt welds
Fig. 2. Detail of welded joints F., J and K., angle iron. G. and H., upper edge of tank.

PLATE IV.

specification, and it will often prove economical to buy this way if mechanical facilities for forming sheets in the shop are not available.

When necessary, however, to form light sheets in the welding shop the lack of machinery should not prove a serious detriment or severe handicap in an oxy-acetylene welded tank construction on a moderate scale. The most ordinary equipment is often sufficient to form light sheets. Cylindrical shells can be formed by bending and pounding the sheet over any round shape and the edges can be flanged with a block or vise and hammer. Rectangular sections are easily bent with a sledge over the edge of an I-beam. A simple "home-made" press can be built of two I-beams, one rigidly fixed to a solid base and the other suspended and so supported that a lever can be attached to bring it with force past the fixed I-beam. A sheet placed between the two may be quickly and sharply bent to the angle desired.

Bending ¼ in. and heavier sheets into cylindrical or rectangular sections without machine tools can be facilitated to a great extent by first heating the parts to be bent with an oxy-acetylene blow-pipe.

If shears are not available an oxy-acetylene cutting blowpipe is an effective, quick and economical means of cutting sheets to size. In fact, under some conditions and unless a quantity of material is to be handled, as it is a cheaper and more adaptable method of cutting, the cutting blowpipe is preferable. It is advisable, however, to clean the cut edges so that no slag will be included in the weld.

Unless the tank being considered is to be used for some unusual purpose the heads, bottoms or tops need not be dished, as the pressures encountered in the type of tanks being considered are not sufficient to warrant this. Flanging these parts will often aid in welding them to the sides or shell. Dished heads often add to the appearance of a tank and simplify the handling of contraction strains.

The edges of sheets ¼ in. thick and heavier should be beveled to about 45 degrees to permit proper welding practice. If the beveling cannot be done when the sheet is sheared it can be effectively accomplished with an oxy-acetylene cutting blowpipe.

Sheets $\frac{3}{16}$ in. thick and lighter, after being formed to the required shape, do not require special edge preparation for welding. Heavier sheet, on the contrary, requires beveling and more careful attention in forming so that misfits and poorly matched sections will not be encountered in the welding.

Welding

Much can be gained in speed, accuracy, and workmanship if drawings including layout of sheets are furnished the welders. If the tank is designed in the shop rough drawings or, at least, sketches will tend to eliminate delays and inaccuracies that often result when work is attempted without the proper working plans.

It may often happen that the welder can find ways of constructing a tank more economically and to better advantage than contemplated by the designer. Frequently an experienced welder has a better knowledge of the preferred practices in his trade than an engineer or designer specializing in other lines.

Jigs are a great help in welding long seams in sheets $\frac{3}{16}$ in. and lighter. The jig may be a temporary holding device consisting of flat straight-edges to weight the sheet down or to which the sheet edges can be securely clamped. It may be a permanent device designed and constructed in production work. As long, however, as a device serves to securely hold the edges of the seam in the correct position and easily accessible to the welder the requirements of a jig are fulfilled. Jigs for quantity production can be so built so as to be semi-automatic in operation, water-cooled and possess other refinements to expedite and improve the work.

Expansion and contraction due to the heat of welding are probably the most important factors, besides good welding practice, to be considered in tank welding. These two factors can be controlled to a large degree on short lengths of light sheets by tack welding the edges. The edges of the seam should be tack welded apart, at from 2½ to 6 per cent, of the length of the weld and then weighted down with narrow strips of steel. If no temporary jig is available, tack welding at intervals of 2 to 6 inches should suffice for emergency purposes. When this method is used and the welded shell proves slightly deformed it can be re-rolled or hammered again to the proper shape and diameter.

Some provision, however, must be made or mechanical means employed to counteract the forces of expansion and contraction in the sheet during the welding. These forces tend to draw the edges apart when the welding is begun and afterwards to gradually draw them together until the edges finally overlap.

More effort is necessary to handle expansion and contraction in sheet ¼ in. thick and heavier than is required for lighter sheet, as the heavier section has a proportionally greater power of contraction unless adequate separation of the sheets relieves the strains. When proper procedures in controlling these forces are carefully followed there is slight danger that expansion and contraction in the sheet will either prove a hindrance to welding or have any ill effects upon the finished work.

Clamps and wedges have been found to be the best means for holding work in position for welding. The end of the seam where the welding is started can be tack welded into place. A clamp made of two strips of the same thickness of metal as the tank, bolted or clamped to the other ends of the seam and bent to conform to the circumference of the shell will hold the edges apart and in the proper position. Clamps or bolts should not be drawn up so tightly as to prevent the edges drawing together gradually as the work progresses. Ordinarily it is the practice to separate the edges in this way about ⅛ of an inch at the end opposite the start of the weld for each foot of the length of the seam. A wedge, having a fairly long point, can be inserted between the edges about two-thirds of the length of the seam away from the end at which the welding is started as an additional means of holding the edges apart. As the welding progresses the edge should be moved along the seam and finally taken out with the end clamps when the work nears completion. A spring leaf or any V shaped piece of metal will serve this purpose.

In welding long seams in this thickness of metal it is necessary to keep the two sides in the same plane. Otherwise the joint will be unsightly and may be poor in quality. An automobile spring leaf ground to a fine edge or a crow bar may be used to raise the depressed side of the sheet. Unless jigs hold the sheets properly some means must be employed for accomplishing this purpose.

If the length of a round tank requires more than one cylindrical section the longitudinal seams on each section may be welded before the circumferential seams but an excellent method of building long cylindrical tanks is to make the longitudinal weld of one ring, then join the next sheet at the circumference of the first ring and follow by welding the longitudinal seam of the second ring. The ends or bottom and top should be welded in last.

Corner joints are not objectionable in tanks that are not subjected to high internal pressure. As it is the tendency to use heavier sheets than necessary to withstand pressure exerted by the weight of the contents in order to obtain either additional wearing qualities or stiffness, corner welds can be considered good practice for the types of small tanks being considered in this treatise. Nevertheless additional strength can be obtained by avoiding corner welds and locating the joints in the body of the tank. To do this will manifestly require additional work and more expense in the preparation of material.

The most common and easily prepared joint for the side seams of round tanks and the sides of rectangular tanks is the butt weld. The lap weld should not be used on this type of tank construction.

The form of joint for use on the end of round tanks and the bottoms of rectangular tanks will be determined by the thickness of the sheet, size of the tank and the weight of the contents. If, for the sake of additional strength, the end or bottom sheet have been dished or flanged, welding the joints is simplified. Variations in the type of joints that are recommended for different purposes are illustrated and described in the accompanying drawings.

Rarely is it necessary to reinforce or brace round horizontal storage tanks. It is more economical to construct a base or foundation of conventional design to distribute and

carry the load. But, there are numerous occasions when it is beneficial to brace and reinforce the top and sides of rectangular, open-top tanks.

This can usually be accomplished easily and economically by cutting angle, band or bar iron to size with the cutting blowpipe and then tack welding it to the section of the tank which it is desired to strengthen or stiffen. If preferable, the bar iron can be heated with the blowpipe and bent to the required shape. This makes the use of bar iron preferable to angle iron as the latter is more difficult to shape. The ends of the bar or angle iron should be welded together. One should not attempt to more than tack weld these to the sides of the tank as continuous welding after the tank has been fabricated tends to buckle the sheet.

Welding Practices

Of equal importance to the proper preparation of the material are correct welding practices. If either is neglected the work is bound to suffer.

Penetrating the full depth of the seam and completely fusing the metal throughout its thickness are foremost requirements in welding tanks. Unless these are accomplished a good weld cannot be produced. The projection of the welding flame is great enough to fully penetrate the depth of the seam on light gauge sheets. On heavier sheet, however, beveling, referred to before, is necessary to form a vee about as wide as the thickness of the sheet to permit full penetration.

A neutral flame is also very essential and an operator working on sheet steel and iron should always be careful to maintain such a flame. The apparatus manufacturers' table should be followed for the correct size welding head or tip to use on various thicknesses of metal. Use of oversize tips or of higher pressures than prescribed usually results in "burning" of the deposited metal.

Ability of welders may be easily and accurately checked by placing strips of welded sheet in a vise, the weld being flush with the face of the vise, and hammering the projecting part of the sheet until the material is bent to right angles or the weld has failed. A study of a failed weld will disclose the cause of fracture which may be due to any or all of the above mentioned causes.

Some sheets of steel may not weld properly which can be checked by first assuring that the welder does good work on some satisfactory steel. In light sheet steel a properly made weld should bend to ninety degrees without cracking.

Either welding by sections or continuous welding can be employed with equally good results. The former is done by first playing the flame along the edges for a short distance as a preliminary heat treatment, then fusing the lower edges together for about two inches without adding any filler material. It is important that this phase of the weld be carefully and completely done in order to assure full penetration. This much accomplished, the welding of the two-inch section is completed by gradually adding metal from the filler rod in ripple layers. The end of a completed section is then fused to the bottom of the last two-inch section completed and the operations repeated to the end of the seam. The welding progresses by these small sections, each being completed before another is started. In continuous welding the welded section advances with each addition of the metal which is made to slant toward the bottom of the vee. The filler material is added continuously to a sloping plane so that the edges of the seam are fused as a part of each layer that is added.

In tank welding when a single vee weld is used a heavily built up joint is not recommended. If sufficient filler material is added to build the weld up not more than fifteen per cent of the vee depth above the surface of the sheet, the best results will be obtained. Should the joint be built up in excess of this amount the inside or under part is weakened by the heavier upper section acting as a fulcrum on the weld. It must be understood, however, that this applies only to single vee welds, that is, welds made from one side of the sheet only. In welding from both sides reinforcement is advantageous up to twenty-five or thirty per cent.

A good quality of filler rod is essential. Ordinary wire or strips cut from the sheet usually do not possess the qualities required of a welding rod. Only a rod that is specially prepared for welding purposes and has the correct chemical and physical properties should be used. When this matter is disregarded and rods of questionable quality are used, regardless of the operator's skill there is no assurance that a good weld will be obtained. Copper coated drawn iron rod clean and free of dirt and impurities and low in carbon, is recommended.

Flux is not generally used in welding sheet steel. One of the most economical features of tank construction by the oxy-acetylene process is the effective manner with which the process lends itself to the utilization of used and scrap material. Discarded flat sheets or old devices from which such sheets can be cut are to be found in almost every industrial plant. If not, such sheets can often be purchased far below the cost of new material.

Open top tanks, round or rectangular, and even some types of storage tanks can be and are being constructed entirely of scrap material with the oxy-acetylene cutting and welding blowpipe. Used sheets for the shell or sides and ends or bottoms can be cut to shape and size so they can be welded together to almost any desired form. The round shell of used sheets may be formed with several longitudinal or circumferential seams and the ends or bottoms formed by welding pieces together and then cutting round or rectangular sections from the built up sheet. Sections for rectangular tanks may be formed from almost any size sheet. By cutting and welding an operator can often fabricate such a tank with no other tools than an oxy-acetylene outfit. A quantity of lubricating oil tanks recently built by a large oil pipe line company from old smoke box iron which ranged from 10 gauge to ¼ in. thick, is an illustration of what can be accomplished with scrap sheets. The sheets for the shells were cut to size with the cutting blowpipe and measured 4x10 and 5x10 feet. These were rolled to form and round sections were cut from the same stock for the ends. These tanks were fabricated entirely by welding, and as the smoke boxes had been scrapped the tanks were built for the cost of the labor and gas alone.

Steam, water or air jacketed tanks can be constructed by welding because of the flexibility of the oxy-acetylene process in fabricating unusual shapes or sections. As such types of tanks are usually built to meet special requirements the cutting blowpipe will ordinarily prove the most economical means of cutting the material to size.

In fabricating jacketed tanks it is, of course, of the utmost importance that the jacket seams be tight. Experience has demonstrated that best results are obtained by building such tanks in complete sections and then assembling these. The methods of preparing the sheets and welding the seams are the same as described for other types of tanks.

The construction of an irregular shaped tank is as easy and economical as regular shapes as far as welding is concerned. Particular care, however, must be taken in preparing and forming the material so that the joints will fit together. Contraction and expansion in irregular shaped pieces can be controlled by the same methods used on rectangular tanks.

If the material is prepared on a quantity production scale or if mechanical means are available it is, of course, more economical to have the openings for connections cut in the sheets before the tanks are welded. If the work is being done entirely in the welding shop better results are obtained by cutting the desired openings with a cutting blowpipe after the tank is fabricated. Doing this obviates the danger of misplaced openings and enables the builder to conveniently adapt any changes in the position or size of connections desired. When making such cuts with the cutting blowpipe the outside edge of the cut should come inside the extreme measurement of the opening, and should thus be in the piece to be removed.

The drawings in Plate IV show different methods of welding fittings to a tank. Whenever possible it is recommended that welded flanges be used on such connections.

As tightness is the principal requisite of a tank of any sort it is essential that the welder test his work to ascertain that the results are as desired. The most practicable way to test an open-top tank is to fill it with water and tap the seams with a mallet. Tapping will bring to light any defects in the welding or hidden stresses that have been set up by expansion and contraction and which might not be discovered without test tapping until after the tank is in service. Any defects can be rewelded to make the tank absolutely tight. Caulking invariably proves to be an expensive method of correcting defects and should not be employed.

Storage tanks, horizontal and vertical, can be more thoroughly tested than open-top tanks. The best and customary method of testing these is to tightly close all openings and then fill the tank with air under pressure of from five to ten pounds per square inch and go over the seams with a brush and soapy water. Or if more convenient, the tanks can be filled with water, and then pounded, not too severely, with a hand hammer or mallet. To give the welded seams a more severe test the water in the tank may be put under from five to ten pounds' pressure, per square inch.

When galvanized sheet is used care should be exercised to restrict the portion from which the galvanizing is burned to as small an area as possible. By carefully manipulating his blowpipe an operator will be able to restrict the burned area to not more than ¼ of an inch on each side of the seam. Those who are practiced in welding galvanized sheets can, however, easily confine the burned part to a considerably smaller area, thus eliminating any possible objection to welding them by the oxy-acetylene process. The welded sections should be finished with a coating of aluminum paint, shellac or other suitable material in additional to being water-proofed. When this is done satisfactory results are assured.

Some of the largest tank manufacturers in the country are building quantities of galvanized iron all oxy-acetylene welded gasoline and oil storage tanks, and in their years of experience they have never encountered an oxy-acetylene welded tank that leaked while in service, either in the weld or in the base material adjacent to the weld. The film of oxide on the outside of an oxy-acetylene weld is an excellent protection to the weld metal under it.

Examples of Tank Welding

To illustrate the methods and practices described, the following examples of tank welding are given. Each is representative of a type of tank commonly used and variations from the procedure outlined need not be radical when constructing tanks of different size or shape.

A Round Open-Top Tank

500-gal. capacity and 4 ft. high.
Calculations for size:

$500 \times .1337 = 66.85$ cu. ft.
$66.85 \div 4 = 16.75$ sq. ft. area of bottom.
Circumference of bottom = 14 ft. 4⅝ in.
Diameter of bottom = 4 ft. 8 in.

Sizes of sheets required are, therefore, one 4 ft. wide and 14 ft. 4⅝ in. long for the shell and one 4 ft. 8 in. diameter for the bottom.

The thickness of sheet required for this size of tank was found to be 16 gauge but assuming that the tank is liable to be subjected to hard usage 12 gauge will be used to obtain additional strength and stiffness.

Care should be taken to cut the shell sheet exactly to size and with square edges and to cut the bottom to a true circle.

The material having been cut, the shell of the tank is formed into a cylinder. If rolls are used, may prove difficult to roll the edges to a perfect circle. They may come out with distorted edges which must be pounded or otherwise bent to conform to the proper circumference of the circle or the finished tank will be off shape and its appearance spoiled. It is better to have the edges depressed about ⅛ in., as welding will tend to straighten the edge sections to the desired contour. If not, they can easily be pounded or pressed into shape after welding.

Next, the ends should be tack welded at one end and clamped at the opposite end. The seam being 4 ft. long, the edges are clamped (⅛ in. for each foot the seam is long) ½ in. apart at the end of the seam opposite the point where the welding begins. It will depend on the speed of the operator whether or not a wedge should be used. If the edges appear to be drawing together too rapidly, a wedge should be applied to hold them the proper distance apart and overcome the force of expansion.

Upon completing the side seam (or seams, if two or more are used), if the shell appears to be out of shape, the distortion can be removed by pounding the section affected.

In welding the bottom to the shell, the latter is set on end and the bottom sheet is placed in position and supported so that it will not fall into the shell. The seam is first tack welded at about 8-in. intervals, so when the welding is begun it can proceed without interruption.

As 12-gauge sheet is only $\frac{7}{64}$-in. thick, some sort of a stiffening ring, preferably of bent angle iron, should be tack welded to the top edge to protect it from damage and to stiffen the tank.

A Rectangular Open-Top Tank.

About 200 gal. capacity and 4 ft. long by 3 ft. wide. Calculations for size:

200 gals. = 26.74 cu. ft.
Area Bottom = 4 ft. × 3 ft. = 12 sq. ft.
26.74 ÷ 12 = 2.23 or 2 ft. 2¾ in., ht. of tank
The tank will therefore measure 4 ft. long, 3 ft. wide and 2 ft. 2¾ in. high.

Assuming that this tank must withstand hard service, $\frac{3}{16}$ in. thick sheets will be used. The sides, ends and bottom are squared off and cut to size with the cutting blowpipe. The cut edges are then cleaned with a rasp or wire brush with the material ready for welding. The sheet for the whole tank is tack welded together at one time. After this is done, the bottom seams are welded and then the side seam beginning at the bottom and welding up. Had it been necessary or economical to weld small sections of sheets together to form the sheet for the sides or bottom, the utility or strength of the tank would not have been impaired.

If desirable to reinforce the sides, this can be done by tack welding bar or angle iron strips around the top edges. Oftentimes it is permissable to stiffen the sides of a rectangular tank with tie rods.

In all cases where tanks of these two types are to be raised above the floor or ground, it is more economical to build a platform or base with a solid top for the tank to rest upon than it would be to reinforce the bottom of the tanks.

PATCHING TANKS

When it is necessary to weld a patch of new metal to close up the hole in a steel tank, the dish patch should be used and will prevent the weld from cracking when it cools. The patch should be prepared about as shown in Fig. 12, and welded in place in

Fig. 12—Dished Patch.

the usual manner with the convex side out, allowing the weld to cool slowly while the flame is played on the convex portion, at the same time rapping it lightly and rapidly with the hammer until it is just flush with the rest of the surface.

Repairing Gasoline Tanks

When using the welding torch to make repairs on leaky tanks which have been used to carry benzine, gasoline or petroleum,

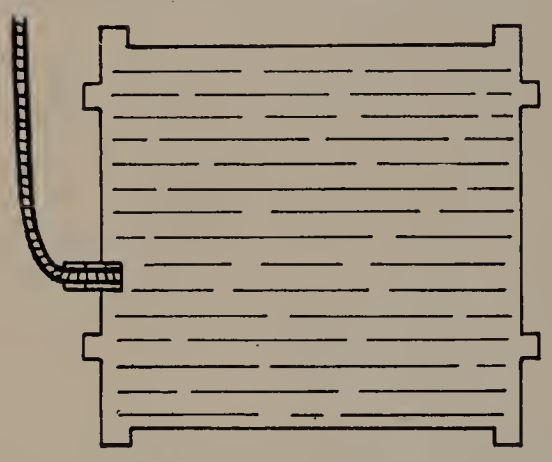


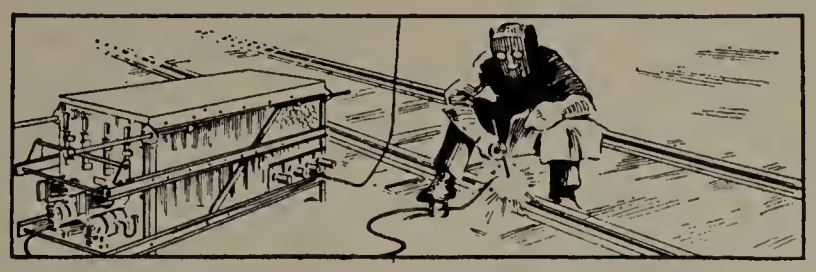
Fig. 13—Safe Welding of Gasoline Tanks.

there is some danger of explosion unless precautions are taken before the weld is started. The best precaution is to clean out such tanks thoroughly with live steam before welding. Another method consists of filling the tank with water at the beginning of the work. A special plug fitted with a vertical tube is screwed into the bung-hole. This tube communicates with the interior of the tank and is long enough so that the water level will show when the tank is filled. It is held by a union so that it can be turned in all directions, and the tank can therefore be welded in any position. If pressure tends to result from the heating of the tank in the course of the work, water is forced from the tube, and all pressure in the tank itself is avoided, and since the vessel is filled with air, the formation of explosive mixtures of gas and air is prevented. (Fig. 13).

Welding Monel Metal Tanks

Monel metal is not difficult for the operator who knows how to weld cast iron or aluminum and how to take care of expansion and contraction. Use a soft flame with an excess of acetylene, so that the second cone extends about ⅝-inch beyond the small flame. The pieces must be beveled and welded as fast as possible so that the metal does not get too hot and form blow holes. Use monel welding flux or borax. Also use rather heavy monel welding rods. When welding sheets of monel, bevel the edges and then add enough metal to more than fill up the groove so that the seam becomes heavier than the sheet itself. Try to melt the metal only once, that is, do not go back over your work to try to fill up the cracks. If a crack occurs in the weld do not go over it while hot. Finish up the seam you are welding, then let it cool; take a hammer and bump the place where the crack is, over a width about three or four times the thickness of the metal, then weld over. When cool beat the sheet back as it was, but never attempt to hammer the sheet while hot. When welding sheets together make a little greater allowance at the ends for welding steel sheets. If you weld fast, however, the allowance for contraction will not need to be so great. See "Monel Metal."

Rail Joint Welding



Introduction

NO other single operation is performed by the welding department of the street railway in such volume as the making of a rail joint. Whenever new track is laid the engineer has to select a joint which, under the given conditions, will promise maximum durability and economy in service, and when it is a question of repairing broken joints he must also look to the matter of doing the job with as little interruption to the traffic as possible. Before the various welding processes were well developed, joints were bolted or riveted, but there are now several methods of producing welded joints which admittedly add to the life of the rail by making it one continuous piece. The perfecting of these processes and the training of operators to observe the best practices are two tasks that will have as their common result the saving of thousands of dollars annually in maintenance costs.

THE LINCOLN PROCESS

The Lincoln process of welding joints consists of welding plates to the ball and base of the rail by the carbon arc, the filler rod being laid in the groove of the seam instead of fed by hand as in repair work. A dynamotor, equipped with suitable surge control for protection against the line fluctuations caused by the starting and stopping of cars, takes the current from the trolley and supplies the proper welding current through the arc. The trolley cable is a light cable supplied with a plug on one end and a trolley hook on the other end. A convenient trolley hook pole can be made by fastening the trolley cable to a long bamboo pole or any suitable pole of strong wood. The trolley hook should be taped on with its back to the pole, and should be kept bright and clean at all times. The ground clamp can be replaced by a heavy weight placed on top of the rail, provided both are clean and smooth. This substitution is particularly useful where repairs are made on old work, because the old rails are so scaly that the best contact surface is on the top.

Details of Operation

Specially constructed apparatus has been developed for this process, and the method of operation has been worked out in detail. Fig. 1 shows the essential details of welding a joint on a groove rail. We have illustrated here the rail, the plates, the filler rod, with flux, the carbon electrode, and the copper "defining bar." This defining bar serves an important purpose, and will be treated more fully later. Note the recommendation that the base seams be welded before welding the head seams, that the edge of the defining bar fit snugly against the rail, not more than 3/16" from the rod, that the filler rod must lie flat against the welding line, that the rod be evenly covered with flux, and that the welding handle be held so as to maintain a definite angle with the carbon electrode. Before running the seam it is good practice to tack the rod lightly at both ends and in the middle by touching it with the arc. In the diagram bolts are indicated with light lines. On new work the plates are bolted to the rail for the purpose of making a strong "set-up," and are removed after the weld is completed. When making reclaim joints it is common practice to leave the bolts in place, and weld the nut to the bolt after finishing the seams. Care should be taken to see that the space between the filler rod and the edge of the defining bar is the same for the full length of the bar.

Preparing the Work

It is one of the primary principles of fusion welding that the perfection of the finished weld depends to a large degree on the preparation of the materials, and although the rail joint is a highly specialized type of weld, allowing the operator to deviate from some of the rigid rules of repair welding, preparing the joint must be done cor-

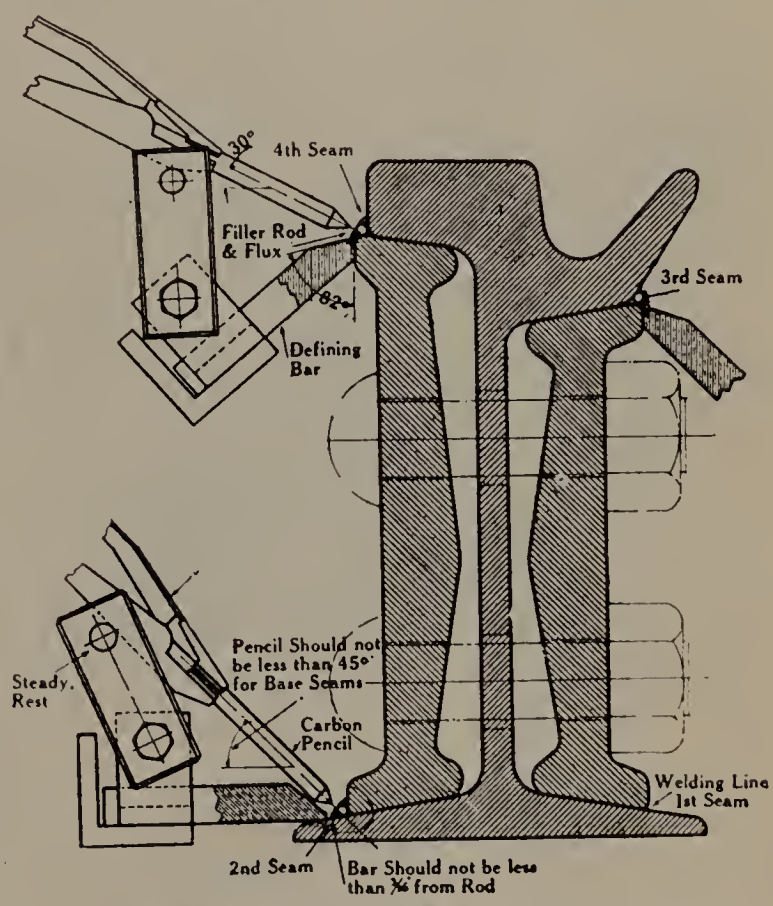


Fig. 1—Details of Lincoln Joint

rectly to secure the results that are sought. The process has been developed with a view to making a sufficiently strong joint at maximum welding speed, but this strength will not be secured if any essential detail of operation is slighted. It should therefore be noted that one of the first things called for is a good mechanical joint between the plate and the rail before the welding is started. Warped or canted plates do not furnish such a joint. The former must be hammered straight before starting to put them in place, and the latter should be made to fit straightly and snugly by the use of shims, as shown in Figure 2. Impact tests have indicated that "short" plates set in with shims have at least four times the resistance that similar plates have when made to "fit" by canting them.

Another essential to good results is clean material. Every particle of dirt or scale or rust that is left in the line of the weld works an injury to the joint. The welder

who attempts to work on dirty stock can tell by the way his arc behaves that the metal is not fusing evenly, and this indication is readily confirmed by sawing through a test specimen. Microscopic examination is not necessary to show the effect.

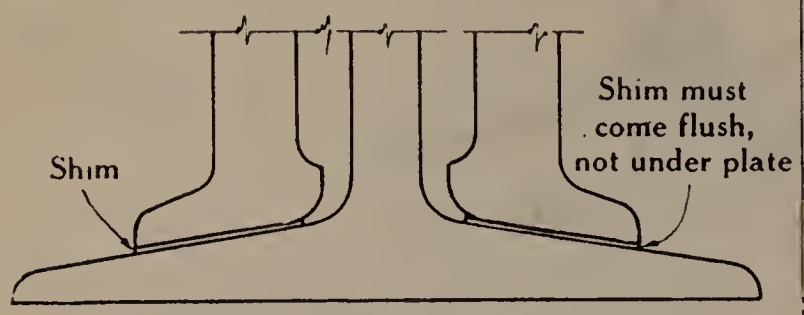


Fig. 2—Tightening Joint with Shims

Maximum durability will not be secured if there is a gap left between the rail ends. If they cannot be made to butt snugly, it

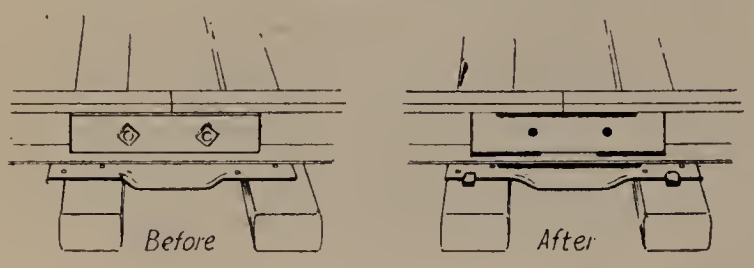


Fig. 3—The Abbott Joint

is worth while to drive in an insert to completely fill the space. The rails should be firmly imbedded in their proper place on the subgrade, not jacked up to a point where

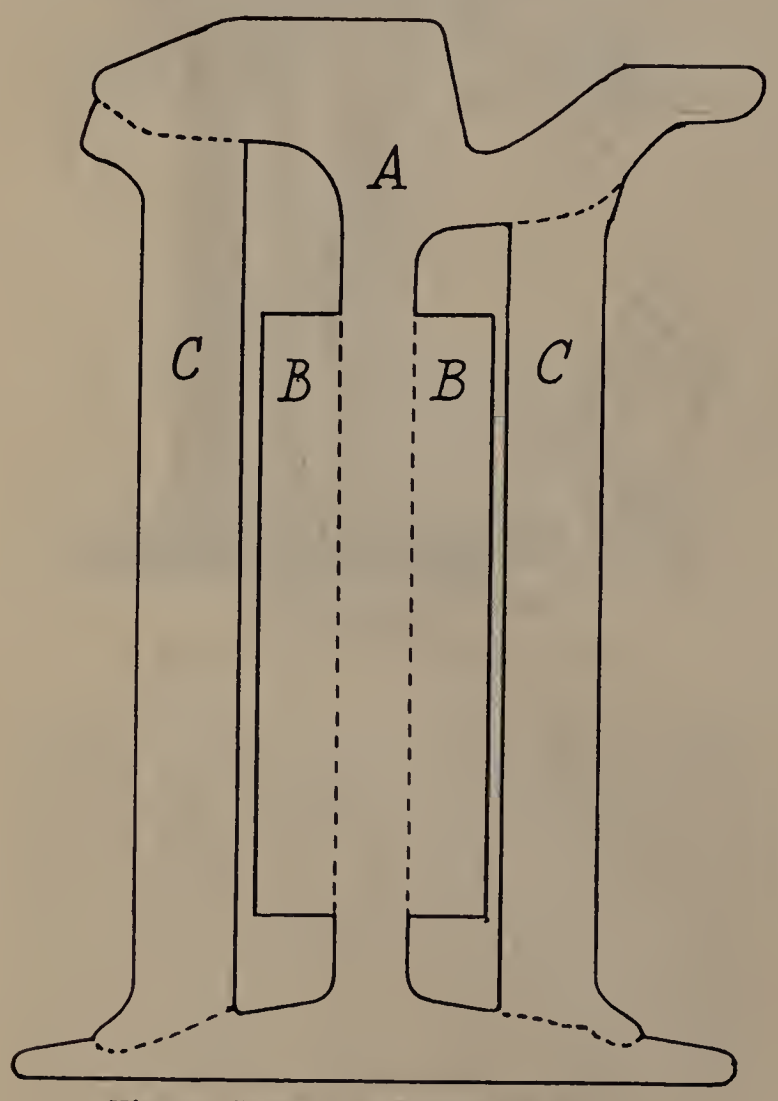


Fig. 4—Repair of Bar Weld Joint

they are out of surface alignment.

The Defining Bar

As reference has been made to that part of the apparatus called the defining bar, it is well to note the reasons for using this device. First of all, it has the effect of confining and directing the arc exactly into the center of the welding line. The bar also serves to hold the filler rod and flux in place and to put the molten metal where it belongs. And if it is cold when the welding starts it concentrates the welding heat in the line of the weld and by conducting heat from the welding area tends to prevent excessive heating of the rail. The bar is largely responsible for the success of the

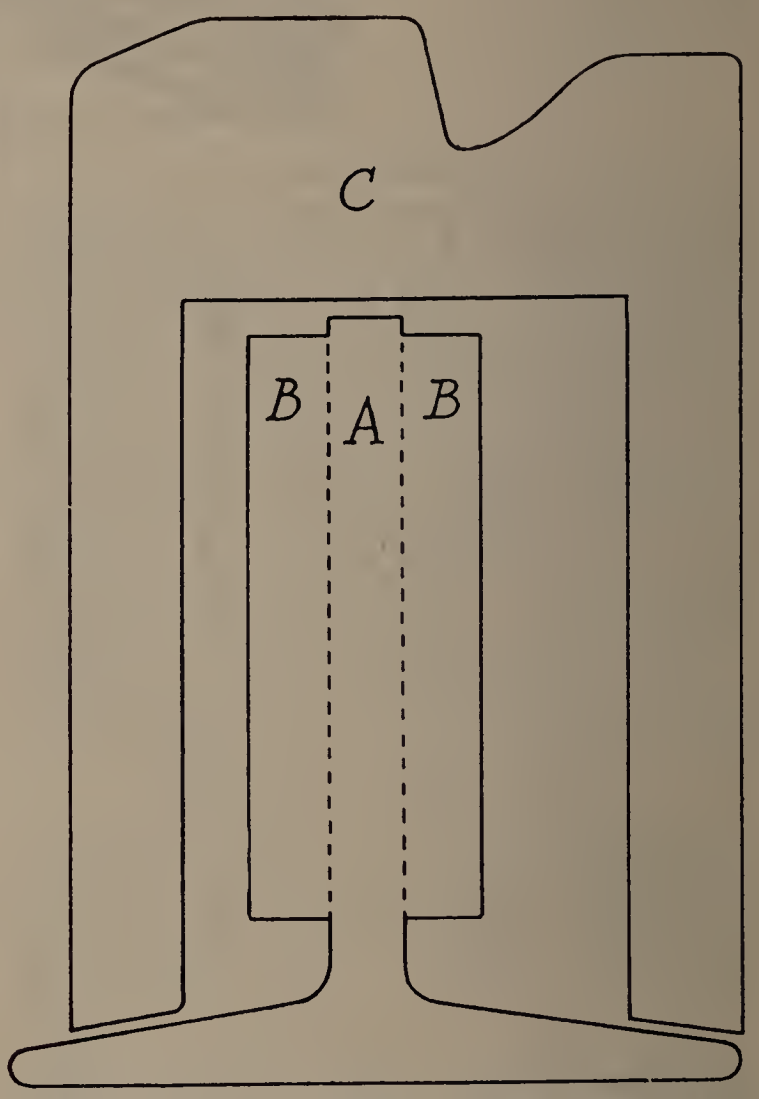


Fig. 5—Temporary Repair of Broken Bar Weld Joint

apparatus in making satisfactory joints rapidly. Its share of the operation is not spectacular but it is none the less important. It will work at its best when kept clean, straight, and cold. Oxides form on the edge very quickly, and when heated it soon becomes dented and scarred. Constant care is necessary to keep it clean enough so that it will fit snug and true against the rail.

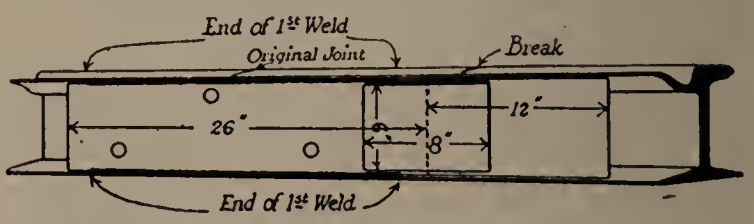


Fig. 6—Repair of Broken Lincoln Joint

Running the Seam

After the parts have been properly prepared, everything "set," and the filler rod tack-welded in place at both ends, the welder strikes his arc an inch or two from the end of the plate nearest the ground clamp or connection and runs the seam in a direction away from the ground connection, being careful not to make a deep crater at the start (which would leave a weakening nick in the rail) but to work gradually into a crater and carry the crater along uninterruptedly until the end of the seam is nearly reached, then gradually lengthening the arc so as to finish the seam smoothly without a pit or nick in the rail. He forces the metal upward into the weld by pointing the arc slightly below the center of the filler

rod, and maintains an arc length that allows the metal to flow smoothly in the crater without bubbling. If there is a space between the rail ends at the base he skips an inch or two in the center of the bottom seam, but does not allow a continuous seam to be interrupted if he can possibly help it.

The Abbott Joint

In localities where rails are subjected to extreme changes of temperature or extremely heavy traffic, a certain percentage of broken joints is almost inevitable. The type of joint described above has given good satisfaction on some of the largest railway lines in the United States, yet there have been some breaks. These breaks have been found to occur outside of the weld, but near it, and consequently they have been ascribed to the heat effect of the welding operation at the top and bottom of the rail acting like nicks in the rail at these points, resulting in a break through the weakened line. The fact that the rail and the plates together are made to form a very rigid section adjoining the weakened area helps to locate the break near the end of the seam. A device known as the "Abbott Joint" is being employed in an eastern city to overcome this condition. Figure 3 shows how the joint is made. Here use is made of a base plate inserted under the joint and resting on ties on either side. The head seam is only sixteen inches long, leaving four or five inches unwelded at each end. Two eight inch welds are made at the ends of the base seams, leaving a six or eight inch gap in the center and one-inch lengths at the extreme ends of those seams unwelded. Then the base of the rail is welded to the base plate, a sixteen-inch seam in the center of the joint. This method is said to give a better distribution of the strains and also provide greater flexibility of the rail at the joint.

Reclamation Work

The Lincoln process is being used extensively for the reclamation of broken joints. The breaks that occur are of two sorts. Very rarely the break is found through the weld. In such cases a repair is easily accomplished by seam welding new plates to the head and base of the rail, outside the old joint. Figure 4 shows a cross section view of such a repair. More often it is the case that the ball of the rail is torn off the web for a short distance. A temporary repair is made by laying a "dutchman" over the break, as shown in Figure 5. This has a heavy cross section and is firmly supported by the base, but it is only an emergency device. As soon as possible a good repair is made by making a "cut-in," i. e., the old rail is cut and a ten-foot section inserted, so the repair really consists of making two new joints.

In Figure 6 is illustrated one method used for the reclamation of seam welded joints.

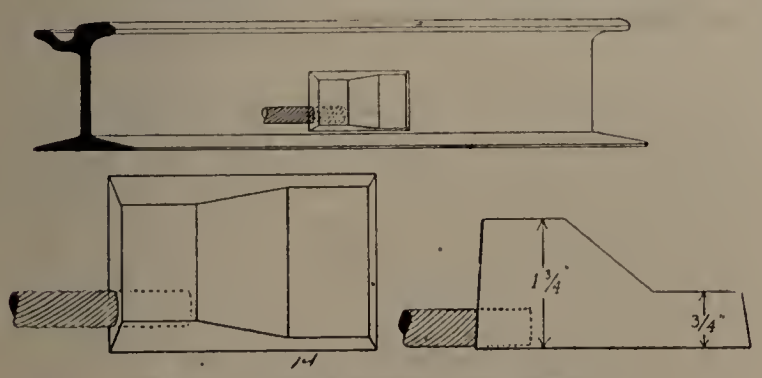


Fig 7—Joining Cable to Rail

A twelve-inch plate abutting the old plate is welded to the head and base of the rail, a second plate 8"x6"x¾" is welded over the seam between the old and the new plates, and a twenty-four inch plate is inserted under the rail, so placed as to support both the old and the new joints.

While these repairs are being made the working parties often pass over sections of the line where it is desired to renew the joint between cable and rail at crossings and switches. A neat and permanent job can be done by using carbon blocks to build a mold around the end of the cable and melting in scrap copper in the form shown in Figure 7. The sketch shows the shape of the mold and the position of the cable when fastened to the rail by welding.

The Thermit Process

The thermit process is described in detail in the chapter on "Thermit Welding."

Cast Iron Rail Welds

Cast iron welds require the use of a large cupola and ladle equipment alongside the track. The added metal is simply drawn from the cupola into ladles and poured into molds at the joint. This type of joint, not being identified with any one of the autogenous processes does not fall within the scope of this book.

THE LORAIN PROCESS*

This method of welding rail joints, introduced by The Johnson Co. of Johnstown, Pa., predecessors of The Lorain Steel Company, in 1897, has had a large application to the welding of street railway rail joints, over 800,000 joints having been installed on a number of the largest street railway systems in the United States. The process consists in welding a bar to each

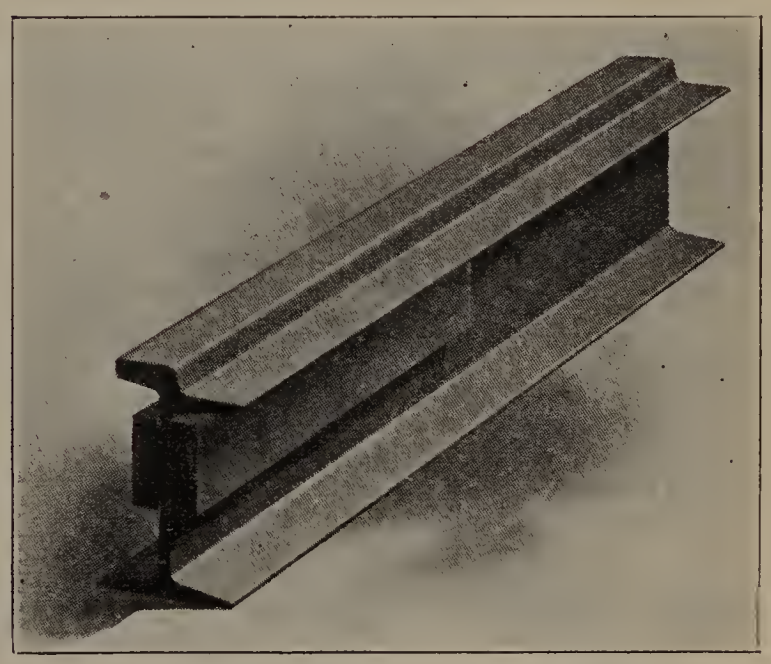


Fig. 8—Section Through End Weld of Lorain Joint

side of the web of the rail across the joint. The bars are attached to the web of the rail by three welds, the first weld is made directly over the rail ends, the other two welds being at the ends of the bars. The rails, at the point where the welds are to be made, are first cleaned with a sand-blast, as are also the bars. The bars are then set in position, one on each side of the web, and the terminals of an alternating current transformer are clamped against the bars on opposite sides of the rail. The terminals are actuated by means of large levers so that hydraulic pressure can be brought against them to force the bars against the rail when a welding heat is reached. The terminals having been clamped in place, the current from a 200 K.W. inverted rotary converter is turned into the welding transformer, which steps the current down to about 7 volts with about 24,000 amperes. This current is confined to a small portion of the bars only by means of projections, or bosses, on the inner faces of the bars, so that the heating effect is localized to those portions only that are in contact with the web of the rail. In

**Written by H. F. A. Kleinschmidt for The Welding Encyclopedia.*

about two and a half to three minutes a welding heat is reached and the parts are forced together under a pressure of about thirty-five tons. The area of the welds in each case is about three and one-half square inches. After the central weld has been made and before the bars have had a chance to cool, the ends of the bars are welded. In the case of the end welds however the pressure is allowed to remain in place for two to three minutes until the metal has cooled below a glowing heat, this having the same effect as the forging of the steel welded, to obtain a uniform heat over the entire end sections of the rails. The process has since been perfected by the Lorain Steel Company and put on a commercially practicable basis and is now being applied. During 1921, joints were butt-welded on tracks in Johnstown, Pa., Boston, Mass., and Philadelphia Pa.

In this process the principle is made use of that a certain flux after being melted and heated becomes a conductor of electricity, its resistance being such however that the current heats it as it passes

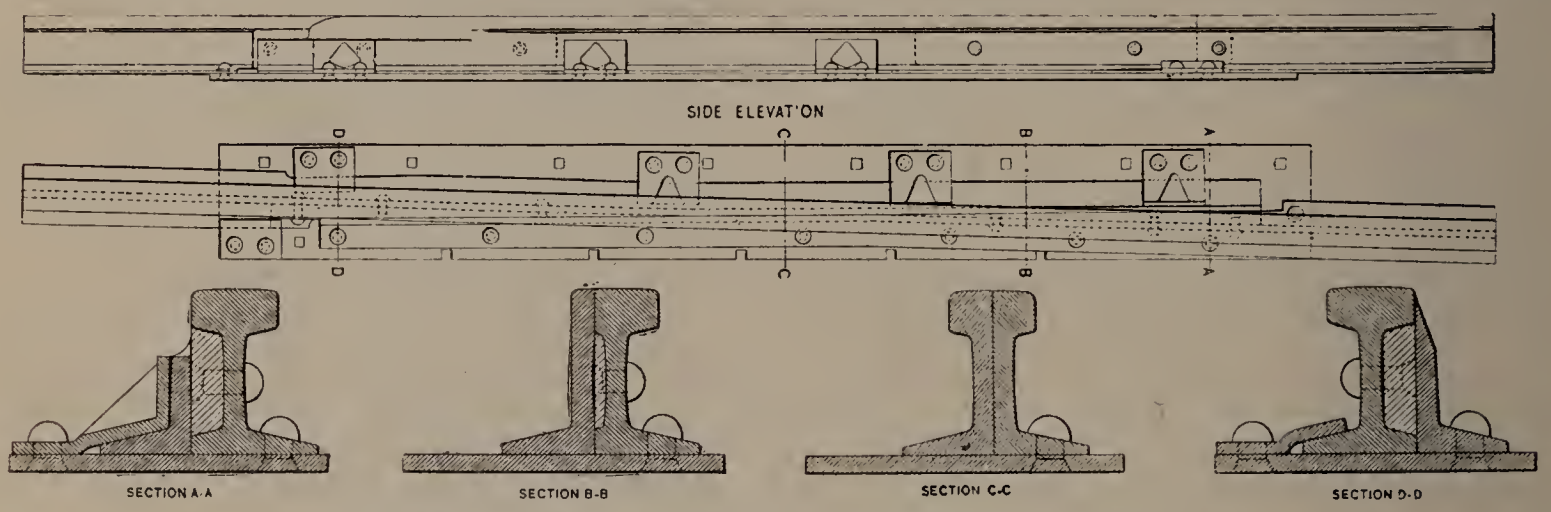


Fig. 9—Detail of Lorain Welded Expansion Joint

under a hammer and producing an exceedingly tough strong weld. After the bars have been welded in place the apparatus moves ahead to the next joint and a surface grinder restores the head, or running surface, of the rail. In cases where old track is being welded, the receiving rail is raised slightly above the other, so that by grinding away the metal on each side of th worn spot a true surface is restored. To further strengthen the rail at the joints a chock, fitting the under part of the rail head is welded in place at the time the central weld is made and gives a support to the rail head at the joints. With bars 1 inch thick and 3½ inches wide a tensile strength of about 330,000 lbs. is secured

through and the hotter it gets the lower the resistance becomes. By setting the rail ends a certain distance apart and applying clay molds around the rail ends the molten flux is confined so that it fills the space between the rails. The current from a 30 K.W. generator is turned into the rails and passes from rail to rail through the molten flux heating it to a high degree above the welding heat of steel. The end surfaces of the rails being in contact with this heated flux themselves come to a welding heat, at which time, by means of suitable clamps the rails are forced together, the molten flux being forced out from between them. As the rail ends are completely immersed in the molten flux no air can get at the

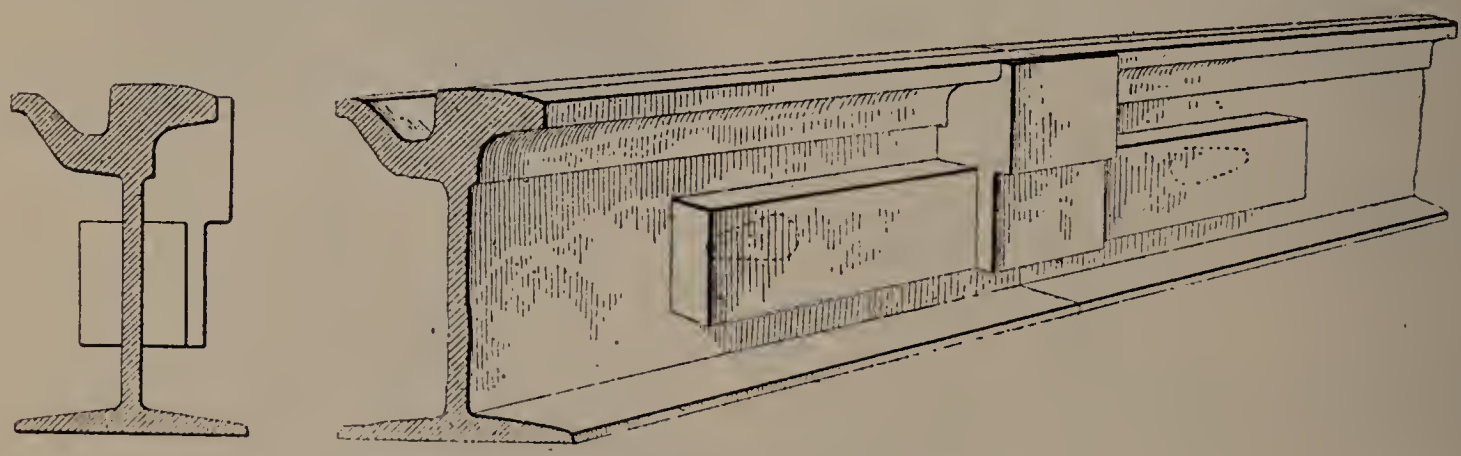


Fig. 10—Lorain Weld on Groove Rail

in the joint (in some cases joints have stood over 400,000 lbs., this being the capacity of the testing machine used). This is considered ample to overcome all stresses incident to changes in temperature between the hottest days of summer and the coldest days of winter. Where rehabilitation work, either on old track or on new construction, is to be undertaken on a large scale this method provides a cheap and satisfactory way of making joints, as has been the experience of large users of this process.

Indirect Resistance Method of Butt-welding Rail Joints

A few years ago the Lorain Steel Company, of Johnstown, Pa., bought the patents of the Jacobs Welding Company for the butt-welding of railway rails by means of interposing a flux between the rails to be heated steel and no oxidation takes place. The pressure is held in place a certain length of time thus producing the forging effect so essential to securing a strong ductile weld of high tensile strength. Experimental tests of a large number of butt welded rails have uniformily yielded a result over 402,000 lbs. tensile strength, this being the full capacity of the testing machine used. After the weld is made a grinder of suitable design removes the upset metal over the head and groove of the rail and restores it to its original shape. This method produces a butt-weld between adjacent rails in which the entire section is welded, without the use of any additional metal of any kind for making the joints. It also enables the hot metal to be worked or forged after the weld has been made, thereby restoring the original properties of

the metal after it has been heated to a welding heat. The current required for the welding of a 9 inch rail weighing 141

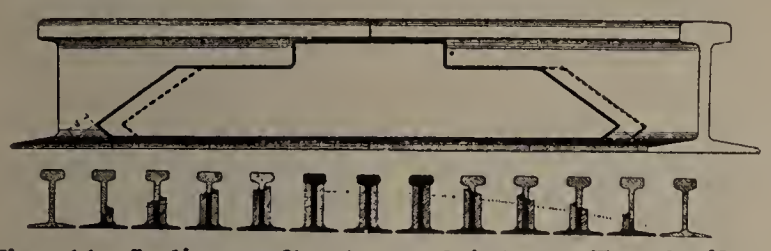


Fig. 11—Indianapolis Apex Joint on Tee Rail

lbs. per yard is about 1,650 amperes at 40 volts, this current being on about three and one-half minutes to a weld.

THE INDIANAPOLIS PROCESS

In the Indianapolis process the welding machine is a rheostat resistance placed between the trolley wire and the rail. A metal electrode is employed. The joint is effected by the application of patented plates, of which there are two types, the Apex and the Simplex. The shape and disposition of the Apex plates are illustrated in Figures 11 and 12, as applied to Tee rails and girder rails and the welding procedure is indicated by the arrow lines in Figure 13. The staggered position of the plates is an important feature of the process, having the

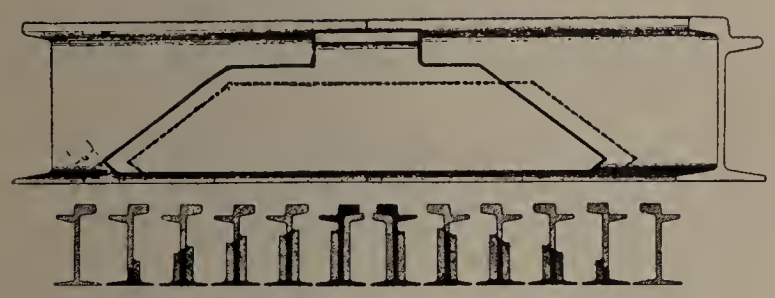


Fig. 12—Indianapolis Apex Joint on Girder Rail

effect of distributing the stresses to which the joint is subjected in service. The Simplex type of plate is similar in shape and application but does not reach as high as the ball of the rail.

Description of Method

The electrode is fluxated steel, iron or other metal of proper and varying constituency and size, averaging $\frac{3}{16}$ inch or ¼ inch in diameter. Suitable electrical current is passed through the welding machine, adapted and regulated according to the nature of the work, and then through a flexible cable to which is attached an insulated welding handle or head holding the metal electrode. This forms the positive, and the part to be welded or added to is the negative.

To start the welding, the electrode is placed in contact and withdrawn just a sufficient distance to form a short arc. This arc makes a pocket or cavity in the negative member and at the same time deposits therein and thereon a molten globule of the electrode. The action is continuous until the electrode is melted down.

A folding screen, or box with top and bottom removed, is used to protect the public from the welding flame. The operator sits on a box, with arms resting on knees, and in such position as to allow free and steady movement. Holding the electrode in both hands, he draws as short an arc as possible moving the electrode evenly and keeping it a uniform distance from the rail. This is the secret of good welds.

Current

Much depends upon the current and energy.

Too much current and too little resistance burns up the melt.

Too little current and too much resistance only "melts." Don't weld.

The electrode "burns" when the voltage is high if the welder is "shorted" or the "electrode" too small in diameter.

The electrode "melts only" when the voltage is low or the electrode too large in diameter.

The electrode "welds" only when the potential of the current is in such relation to the electrode that the arc will not only form a "molten globule" of metal, but at the same instant form a "cavity" or "pocket," into which the base of the globule is deposited.

This makes a deep-seated, perfect weld.

Procedure

In case of old rails, remove rust, grease, pitch or moisture, using an old file or wire

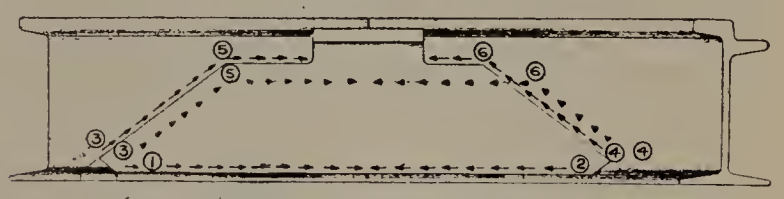


Fig. 13—Order of Welding, Apex Joint

brush, and, if necessary, the carbon arc.

Align rails for gauge, butt joints tightly together at head of rail; surface and shim to base level, disregarding top surface, which should be ground or welded and ground to correct level after joints are applied.

In case of old track, with open joints, insert a "dutchman" cut from a rail of the same section, to completely fill the opening between rail ends before applying plates.

Welding plates are drilled for temporary bolting to rail and should be used in pairs, so that the ends of the plates are not directly opposite each other. After bolts are partly tightened, the plates should be driven down to a tight bearing on the flanges of both rails, and bolts drawn tightly.

Spot each end of each plate first on the base line, then on the top line, for a distance of about 1 inch, to insure holding the plate in position and to resist the tendency to kink or creep during the welding.

Welding should be done as follows.

Run a heavy fillet of steel around edges of plates, drawing a pocket or cavity in both the edge of the plate and the rail. This is important. And at the same time deposit a globule of the molten electrode, filling in the cavity and building up at least ¼ inch.

Weld plates as follows:

A—Weld on base line from each end to center.

B—Weld opposite plate the same.

C—Return to first plate and weld from the base upward on the sloping cut on each end of the plate.

D—Weld both ends opposite plate in similar way.

E—Return to first plate and weld along top of plate, beginning at end and welding to center.

F—Weld top of opposite plate in same manner.

G—Do not attempt to weld across the under-cut at ends of plates, as the point is cut off to prevent joining the two lines of welding.

The object of alternating in the welding, as well as the staggered position of the plates, is to reduce to a minimum the heating of the rail and equalize the expansion and contraction during the application of the joints.

In event a cooling check develops in the fillet of steel, weld a layer over the checked portion.

Track Repairs

When not in use for welding rail joints the welding outfit can be used for making repairs to worn tracks, frogs and crossings. The following instructions, covering different grades of work, have been issued by the manufacturers:

Instructions for Welding on Manganese

Remove all foreign substances; even cleanse with gasoline, if necessary.

Weld slowly and intermittently. Rapid and constant welding must be accompanied by quenching, either by pouring water on the adjacent parts, **not on the weld,** or by laying a piece of metal on the weld to conduct away the heat.

In building up frog or mate points, weld as wide as possible at the base, tapering toward the top.

Before building up a piece of broken or crumbled manganese, look for porous or honey-combed structure underneath, and **weld only on solid metal.**

Experiment with a piece of scrap manganese as a guide for heat limit.

Filling Cups or Low Joints

Use a straightedge and mark at least 1 inch beyond the depression.

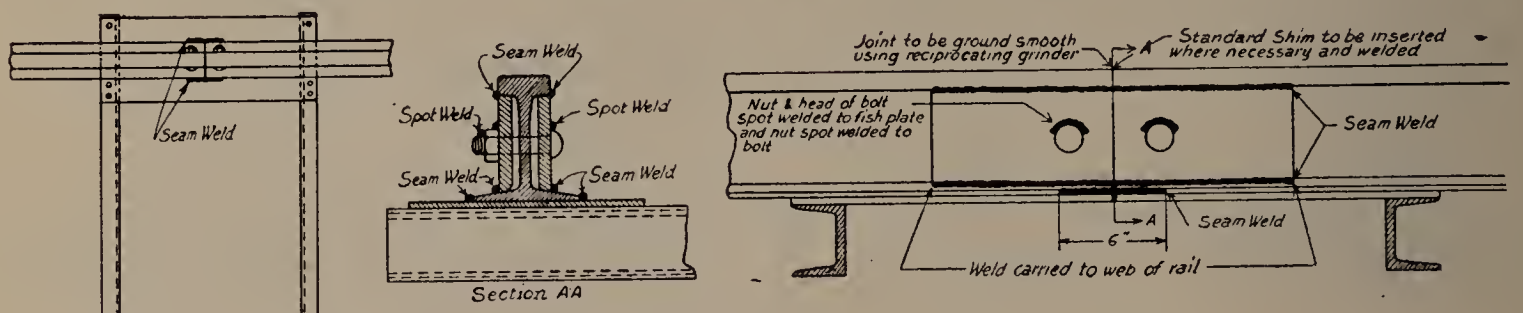


Fig. 14 — Seam Welded Joint on Steel Ties, City of Detroit.

Weld lengthwise, applying an even layer of steel along the gauge of the rail head. Join next layer to edge of first, and so on, covering the width of the head. This, when neatly done, will require very little grinding and leave no holes in surface when finished.

Building Up Rolled Rail Special Work

Have parts to be welded free from moisture, dirt or grease.

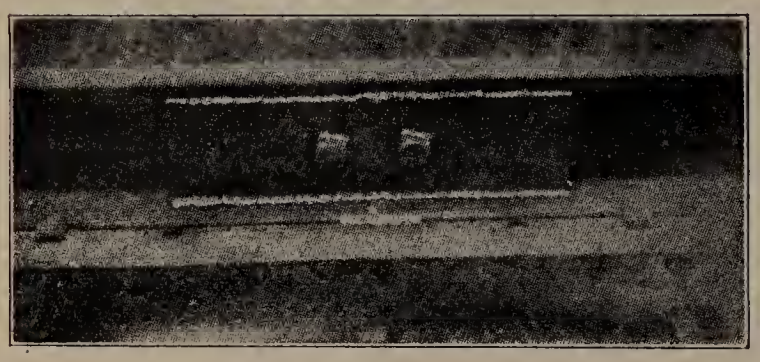


Fig. 15—Appearance of Metallic Arc Welded Joint

If more than two layers are necessary, allow to cool before applying last layer.

The built-up part must rest on a solid base.

Use two pieces of carbon as a form in building up points.

This facilitates welding and obviates edge grinding.

METALLIC ELECTRODE PROCESS

Although the usual practice in welding rail joints is to employ a welding machine which takes the current from the trolley, gasoline driven generators are used to a considerable extent. An especially practical case for the use of standard type welders on track work is new construction, for it allows the work to go on ahead of the overhead construction and independently of it. An extensive new construction program was carried out in the city of Detroit, Mich., in the Spring and Summer of 1921, in which all joints were made by the metallic arc welding process, supplemented by the use of arc welded rail bonds. Complete details of the standard type of joint for rails laid on steel ties are shown in Figure 14.

Before welding the ties and rails were assembled and blocked up approximately to grade by means of concrete block made for this purpose during the past winter. A perfect adjustment of grade and alignment is not possible so just before pouring the concrete foundation another final adjustment was made.

Standard joints between rails are made by welding splice bars, twenty inches long and three-fourths inch thick, to the ball and base of the rail. Splice bars are held in place for welding by two one-inch bolts. Figure 14 is from a blue-print giving specifications for standard joint welding for rails on steel ties. Seam welds are run the entire length of the splice bar, fusing it to the ball and base of the rail. The rails are welded together at the base on each side; and the base of the rail on each side is welded to the tie plate on a line opposite the line joining the centers of the bolts.

The bolt head is fused with the splice bar by what is termed a "spot" weld in street railway work; and on the other side the nut is fused to the splice bar and to the bolt itself. Where joints are not tight, the specifications call for the insertion of a standard shim, which is to be welded in place. Figure 15 shows a completed joint on the inside of a rail. The rail joints are staggered and both sides of the base of the rail opposite a joint are also welded to the tie plate. This is done on both sides of the rail.

Additional welding is used to perfect the electrical circuit. Beginning at the joint every other tie is welded to the base of the rail and on one tie per rail length located midway between joints the two tie plates are each spot welded at the four corners to the cross channels as well as to both sides of the bases of the two rails. A 0000 arc welded cross bond is installed between tracks every five hundred feet. All this insures a perfect cross bond between rails and makes it practically impossible for an open to occur in the negative return circuit, for if every joint were broken there would still be an electrical by-pass around the joints through the intermediate welded ties and opposite rail.

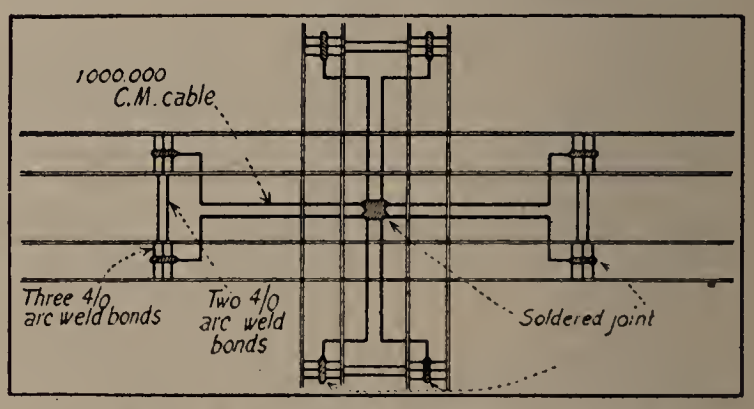


Fig. 16—Bonding Special Layouts

In special work all joints are made with six bolt fishplates. A 0000 bond is attached to the rail at each end of the fishplate, or, in case there is not room enough, a short V bond is used and welded to the base of the rail. The use of this extra

bond is justified because the joint is more liable to fail than joints in tangent track. and there is only a small expense involved in taking this extra precaution against a broken circuit. It also gives the wood tie construction in the special work the same electrical capacity as the steel tie construction on tangent tracks.

In addition to the complete bonding of the rail joints, special work layouts are s' unted by an unusual amount of copper. Figure 16 is a sketch of a typical double track intersection with the extra bonding indicated by heavy black lines. The two rails of each of the eight tracks approaching the intersection are bonded together with three 0000 standard copper arc weld bonds. The inner rails of the two tracks at the four approaches are similarly bonded with two 0000 arc weld bonds.

The mid point of the three bonds between the rails of each track is then connected to the similar cross bonds of the same track at the opposite side of the special work by a 1,000,000 circ. mil stranded bare copper cable, the connection being made with soldered joints which are painted with black insulating paint and wrapped. The entire cables and cross bonds are also painted. There are thus four of these 1,000,000 circ. mil cables, two in each direction, intersecting at the center of the special work layout, and they are all tied together at this point in a soldered joint. These cross cables are laid in the devil strip in a wood trough filled with a mixture of 75% pitch and 25% tar and a small amount of fine gravel. At outlying points the same system of bonding special work layouts is used except that the size of the cross cables is reduced. The sketch of this bonding scheme reproduced herewith gives a quicker understanding than can be obtained from the description. It makes it possible to lift out an entire layout without disturbing the return circuit.

RULES AND REGULATIONS

A. S. M. E. Boiler Code

1918 Edition

Rules for the Construction of Stationary Boilers and for Allowable Working Pressures

PAR 186. **Welded Joints.** The ultimate strength of a joint which has been properly welded by the forging process, shall be taken as 28,500 lb. per sq. in., with steel plates having a range in tensile strength of 45,000 to 55,000 lb. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

Par. 209 The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except when the stays are welded and have a larger cross-sectional area at the weld than at some other point, in which case the strength at the weld shall be computed as well as in the solid part and the lower value used.

Note: The following recommendations are substantially the same as Steamboat Inspection Service Rules, which will be found in this section. **These rules do not apply to boilers which are subject to federal inspection and control, including marine boilers, boilers of steam locomotive and other self-propelled railroad apparatus. See Dep't. of Commerce Rules.**

Recommendations for Repairs when Made by Welding and Reinforcing by the Electric, Oxy-Acetylene, or Other Processes From General Rules and Regulations Prescribed by the Board of Supervising Inspectors, U. S. Steamboat-Inspection Service.

All calking edges on internally fired boilers may be reinforced by these processes.

Calking edges of the shells of externally fired boilers, above the fire line only, may be reinforced.

Cracks extending from edge of lap to rivet, except on seams below the fire line in externally fired boilers, may be welded.

Cracks not exceeding 30 in. in length in back connection sheets, wrapper sheets, bottoms of combustion chambers, heads, and other stayed surfaces may be repaired by welding.

Where cracks are repaired by welding, holes shall be drilled entirely through the plate at each extreme end of the crack, except in small cracks from rivet to calking edge.

Circumferential or lengthwise cracks not exceeding 16 in. in length in plain or corrugated furnaces may be welded.

Where plates in back sheets of back connections, wrapper sheets of sides and bottoms of back connections of any boilers, side sheets and legs of furnaces and bottoms of furnaces of fire-box boilers, and other stayed surfaces are reduced in thickness not exceeding 40 per cent of the original thickness, they may be reinforced, such reinforcing not to exceed an area of 200 sq in. in any one plate.

When such reinforcing extends over stays and braces, such stays and braces shall come completely through the reinforcing so as to be plainly visible to the inspectors.

When the corroded portion of stayed or riveted surfaces of the back sheets or wrapper sheets or bottoms of back connections of any boilers, or side sheets and bottom sheets of furnaces or legs of firebox boilers exceeds 300 sq. in., the same may be repaired by the removal of the corroded portion and the replacement thereof by a new piece of plate, the edges of the new plate being welded in position.

Staybolts, braces, or rivets shall pass through the body of the new plate as before, the area of the new piece not to exceed 24 by 24 in., or 30 in. in any one direction, the welded edges to be V'd or beveled along the joint prior to welding.

Where plates of shells and other parts of internally fired boilers subject to tensile strain are reduced in thickness by corrosion not to exceed 25 per cent of the original thickness, they may be reinforced, such reinforcing not to exceed an area of 200 sq. in.

Where calking edges and laps have been reinforced, local inspectors shall require the rivets to be cut out and redriven if they find by inspection that it is necessary.

No welding shall be allowed in cracks in the shell plates or other plates subject to tensile strain.

Cracks extending through rivet holes in single-riveted or double-riveted seams in stayed surfaces of back connections of any boilers or side sheets of legs or bottoms of fire-box boilers which are stayed surfaces may be welded up to a length of 6 ft. exclusive of rivet holes.

Where cracks extend through rivet holes in stayed surfaces, the piece extending from the rivet to the edge of the lap may be removed where convenient to do so, and the place where the piece has been removed may be replaced by being built up and reinforced by either of these processes.

Where leaks develop around staybolts and the staybolts are otherwise intact, the nuts may be removed from the ends of the staybolts, and the staybolts may be welded into the shell by welding a beveled collar or ring around the staybolt. The width and depth of such collar shall equal one-half of the diameter of the staybolt. In all such cases of applying welding rings or collars around staybolts, the material shall be hammered while in a glowing state as it is applied.

In all cases where metal is deposited on stayed surfaces, the operator shall hammer, when practicable, the deposited metal while it is in a glowing state.

Cracks in wrought-iron or wrought-steel headers, and cracks or sand holes in cast-steel, semisteel, ferrosteel, malleable-iron or cast-iron headers, manifolds, crosses, tees, and ells may be repaired by welding cracks or flowing metal into sand holes. Such repaired material other than headers and manifolds shall be subjected to a hydrostatic test of three and one-half times the working pressure after such repairs are made. Reinforcing by building up of any of the above-mentioned articles other than headers shall not be allowed.

When crown-bar bolts have deteriorated or wasted away at top of combustion chamber under the crown bars, such deterioration not to exceed 25 per cent of the original diameter of the bolt, such bolts may be built up or reinforced by any process of autogenous welding.

Where tube sheets of boilers have deteriorated not to exceed 25 per cent of their original thickness, or where cracks have developed in tube sheets, the same may be reinforced and repaired by any process of autogenous welding, and the beading on the end of tubes may be welded to the tube sheets by the same process.

October 24, 1919.

A. S. M. E. BOILER CODE

Part I—Section IV

Preliminary Report on Rules for the Construction of Unfired Pressure Vessels.

Note: When this Section is incorporated in the Boiler Code, it will be desirable to add the words "AND OTHER PRESSURE VESSELS", at the top of front cover and of the title page and on page 3 of the Code. Also the sentence in italics on page 3 will be changed to read, as follows:

> These rules do not apply to boilers and other pressure vessels which are subject to Federal inspection and control.

Also to insert, after bracket in line beginning Part I, the following:

Section IV—Unfired Pressure Vessels

Definitions

The vessels to which these rules apply are divided into two classes:—

Class A—Vessels for containing liquids above the atmospheric boiling point, inflammable substances, or any gas, and limited in size to those over 6 in. in diameter, more than 1.5 cu. ft. in volume and carrying over 15 lb. pressure per sq. in.

Class B—Vessels for containing liquids, the temperatures of which are under control so as to be below atmospheric boiler point and limited in size to those over 9 in. in diameter, more than 4 cu. ft. in volume and carrying over 30 lb. pressure per sq. in. but not to exceed 100 lb. pressure per sq. in. For pressures over 100 lb. per sq. in. the rules for Class A vessels apply.

Material

These vessels may be constructed of any metal complying with the following rules:—

The maximum allowable working stress used in any of the metals selected shall be determined by the following formula:—

For Class A Vessels:—

$S = 0.0125\ E\ (e + 8)$ but not more than $0.4\ E$.

For Class B Vessels:—

$S = 0.0125\ E\ (e + 16)$ but not more than $0.65\ E$.

where

S=Maximum allowable working tension stress, lb. per sq. in.;

E=Elastic limit of material used;

e=Elongation of material used, in per cent, in 8 in.

Working stress in rivets in single shear shall be taken as 80 per cent of S;

Working stress in rivets in double shear shall be double that of single shear.

Staybolt values for allowable stress per sq. in. of net section shall be taken as follows:—

When e is not over 10 per cent=60 per cent of S;

When e is from 10 to 20 per cent=70 per cent of S;

When e is over 20 per cent=80 per cent of S.

Class A Vessels may be constructed of materials specified in the A. S. M. E. Boiler Code (Edition of 1918) in which case the formula above given need not be used.

Class A Vessels shall be built in accordance with the Rules of construction, which apply, of the A. S. M. E. Boiler Code (Edition of 1918) except Par. 186 which shall read as follows:—

> The ultimate strength of a joint which has been properly welded by the forging process shall be taken as 65 per cent of the tensile strength of the plate.

and Par. 269 to 328, inclusive.

Class B Vessels may be constructed of material specified in the A. S. M. E. Boiler Code (Edition of 1918) in which case the formula above need not be used.

For Class B. Vessels, steel of untested tank quality may be used, assuming the tensile properties below:—

Tensile strength, lb. per sq. in.....48,000
Yield point, lb. per sq. in.....25,000
Elongation in 8 in.....20 per cent

All Class B Vessels shall be constructed in accordance with the rules of Construction which apply, of the A. S. M. E. Boiler Code (Edition of 1918) with the following exceptions:—

Par. 186—rewrite as follows:—

> The ultimate strength of a joint which has been properly welded by the forging process shall be taken as 65 per cent of the tensile strength of the plate. The ultimate strength of a joint which has been properly welded by the autogenous process, may be used in Class B pressure vessels only and shall be taken as 50 per cent of the tensile strength of the plate.

Note: A joint committee of the A. S. M. E. and the American Welding Society is now (Jan —1921) working on a new code.

Department of Commerce

Steamboat Inspection Service, Ocean and Coastwise†

General Rules and Regulations Prescribed by the Board of Supervising Inspectors' Welding and Reinforcing by the Electric, Oxyacetylene, or Other Processes*

NO repair work by any welding process shall be allowed on marine boilers until coupons showing the character of the work proposed to be done by the applicant shall have been tested and submitted, together with an explanation and report of the test, to the local inspectors of the district where the work is to be done. The local inspectors shall then satisfy themselves whether or not such process can be used with safety on the boilers of steam vessels.

No person shall be allowed to make repairs to marine boilers by any of these processes without a permit from the local inspectors of the district in which the repairs are to be made, which permit will be issued upon satisfactory evidence that the applicant is competent and thoroughly understands the process by which the repairs are to be made. The permit will be cancelled upon satisfactory evidence of poor workmanship or the use of improper material or flux.

The following repairs may be made by any process when made by an operator who has received a permit required by the preceding paragraph from the local authorities.

All calking edges on internally fired boilers may be reinforced by these processes. Calking edges of the shells of externally fired boilers, above the fire line only, may be reinforced, but no welding shall be permitted below the fire line.

Cracks extending from edge of lap to rivet, except on seams below the fire line in externally fired boilers, may be welded.

Cracks not exceeding 30 inches in length in back connection sheets, wrapper sheets, bottoms of combustion chambers, heads, and other stayed surfaces may be repaired by welding.

Where cracks are repaired by welding, holes shall be drilled entirely through the plate at each extreme end of the crack, except in small cracks from rivet to calking edge.

Circumferential or lengthwise cracks not exceeding 20 inches in length in plain or corrugated furnaces may be welded.

Where plates in back sheets of back connections, wrapper sheets of sides and bottoms of back connections of any boilers, side sheets and legs of furnaces and bottoms of furnaces of fire-box boilers, and other stayed surfaces are reduced in thickness not exceeding 40 per cent of the original thickness, they may be reinforced, such reinforcing not to exceed an area of 400 square inches in any one plate.

When such reinforcing extends over stays and braces, such stays and braces shall come completely through the reinforcing so as to be plainly visible to the inspectors.

When the corroded portion of stayed or riveted surfaces of the back sheets or wrapper sheets or bottoms of back connections of any boilers, or side sheets and bottom sheets of furnaces or legs of fire-box boiler exceeds 400 square inches, the same may be repaired by the removal of the corroded portion and the replacement thereof by a new piece of plate, the edges of the new plate being welded in position.

Stay bolts, braces, or rivets shall pass through the body of the new plate as before, the area of the new piece not to exceed 24 inches by 24 inches, or 30 inches, in any one direction, the welded edges to be V'd or beveled along the joint prior to welding.

Where plates of shells and other parts of internally fired boilers subject to tensile strain are reduced in thickness by corrosion not to exceed 25 per cent of the original thickness, they may be reinforced, such reinforcing not to exceed an area of 200 square inches.

Where calking edges and laps have been reinforced, local inspectors shall require the rivets to be cut out and redriven if they find by inspection that it is necessary, but in no case shall they be called.

Cracks not exceeding 24 inches in length in the shells of internally fired boilers may be repaired by reinforcing the plate to cover the crack with a piece of tested steel plate of not less than one-fourth inch in thickness, said reinforcing plate to be drilled with three-fourths inch holes not more than three inches apart. Such holes in the reinforcing plate shall be countersunk and spot welded through these to the shell of the boiler. The edges of the reinforcing plate shall also be welded to the shell of the boiler. This form of repairs shall only be allowed when made by the electric metallic arc process. Cracks not exceeding 24 inches in length in the shells of externally fired boilers above the fire line and in mud and steam drums may be reinforced by the above process.

Cracks extending through rivet holes in single-riveted or double-riveted seams in stayed surfaces of back connections of any boilers or side sheets of legs or bottoms of fire-box boilers which are stayed surfaces may be welded up to a length of 6 feet exclusive of rivet holes.

Where cracks extend through rivet holes in stayed surfaces, the piece extending from the rivet to the edge of the lap may be removed where convenient to do so, and the place where the piece has been removed may be replaced by being built up and reinforced by either of these processes.

Where leaks develop around stay bolts and the stay bolts are otherwise intact, the nuts may be removed from the ends of the stay bolts, and the stay bolts may be welded into the shell by welding a beveled collar or ring around the stay bolt. The width and depth of such collar shall equal one-half of the diameter of the stay bolt. In all such cases of applying welding rings or collars around stay bolts, the material shall be hammered while in a glowing state as it is applied.

In all cases where metal is deposited on stayed surfaces, the operator shall hammer, when practicable, the deposited metal while it is in a glowing state.

Cracks in wrought-iron or wrought-steel headers, and cracks or sand holes in cast-steel, semisteel, ferrosteel, malleable-iron or cast-iron headers, manifolds, crosses, tees, and ells may be repaired by welding cracks or flowing metal into sand holes. Such repaired material other than headers and

*As amended, 1922.

†*These rules are the same as in the case of Regulations governing "Rivers" and "Great Lakes."*

manifolds shall be subjected to a hydrostatic test of three and one-half times the working pressure after such repairs are made. Reinforcing by building up of any of the above-mentioned articles other than headers shall not be allowed.

When crown-bar bolts have deteriorated or wasted away at top of combustion chamber under the crown bars, such deterioration not to exceed 25 per cent of the original diameter of the bolt, such bolts may be built up or reinforced by any process of autogenous welding.

Where tube sheets of boilers have deteriorated not to exceed 25 per cent of their original thickness, or where cracks have developed in tube sheets, the same may be reinforced and repaired by any process of autogenous welding, and the braiding on the ends of tubes may be welded to the tube sheets by the same process. Any feature of welding not covered by these rules may be accepted and approved by the Supervising Inspector General if, in his opinion, it meets with the obvious intent of the rule. (Secs. 4405, 4418, R. S.)

Lloyd's Register of Shipping

Activities*

THE Sub-Committee has also arranged for experiments and tests to be carried out by Dr. Marchant, Professor of Electrical Engineering at the University of Liverpool, in connection with electric welding, in order to ascertain the best electrical conditions to be employed in the process of arc welding, and also to determine whether the variations in the current and voltage across the arc during welding can be used as a criterion of the satisfactory nature of a weld after it has been completed.

Although electric arc welding has been employed for many years for ship repair work, its use has been hitherto confined to those parts of the structure which are not likely to be exposed to severe stresses, and it is only since the early part of the war that appreciable progress has been made in the developments of welding, which would appear to justify the consideration of proposals to use electric welding as a means of replacing the usual riveted connections of structural work of primary importance.

In 1917, the Committee of Lloyd's Register arranged for an exhaustive series of tests to be carried out under the direction of the Society's Chief Ship Surveyor, to determine, as far as possible, the general trustworthiness of structural connections effected by electric welding, and their capacity to withstand the strains to which they would be subjected. The results of the experiments made were considered by the Technical Committee of the Society, and on their recommendation the General Committee adopted, as a tentative measure, provisional Rules for the classification in Lloyd's Register Book of vessels electrically welded, subject to the notations "Experimental" and "Electrically Welded."

The Committee also formulated their requirements regarding the tests to be complied with by all systems of electric welding for which approval was desired, and a notice was issued stating that the Committee were prepared to consider applications from any Electric Welding Companies, for their processes to be recognized by the Society for use in ship construction, and for their names to be inserted in a list of Companies whose processes have been approved as fulfilling the Society's conditions.

Plans for the first vessel in which the butts, seams and other connections are to be electrically welded have been submitted, and approved by the Committee. This vessel, which is about 150 ft. in length, and in which the use of rivets will be entirely dispensed with, is now nearly ready for launching and the behavior of the vessel after completion will be carefully followed by all who are interested in the new system of construction.

Applications have also been received by the Committee for approval of a scheme of construction in which both riveting and welding processes shall be employed, but in such a manner that the vessel might be classed without the notation "Experimental."

After careful consideration the Committee approved, in the case of a vessel framed on the longitudinal system, a design in which electric welding will be employed in the construction of the bulkheads and for the attachment of the longitudinal frames to the structural plating, this approval being contingent upon a special notation being inserted against the vessel's name in the Register Book.

An extract from the report of the Society's operations during the year 1918-1919. This is the latest report (Jan., 1921).

Tentative Regulations and Tests to be Complied with by All Systems of Electric Welding for Which the Approval of the Committee of Lloyd's Register of Shipping is Desired.*

1. The cost of carrying out the required tests must be borne by the proprietors of the system of welding tested.

2. All test pieces must be prepared in the presence of a representative of the Society and all tests must be carried out under his supervision.

3. The steel used in the preparation of the specimens must be ordinary ship steel, having a tensile strength of from 28 to 32 tons per square inch.

4. The welding of all specimens must be executed in accordance with the company's usual practice.

5. A chemical analysis must be made of the metal of an electrode and of the deposited material of a weld made by the same electrode.

6. A series of microphotos, magnification 100 diameters, must be prepared showing the structure of the material of the weld, that of the plain plating adjacent to the weld, and that of the actual junction between the original and the added material.

7. Tensile Tests. Two sets of tensile test pieces with butt joints shall be prepared, each set consisting of specimens of different thickness, viz.: ¼ in., ½ in., ¾ in., and 1 in., together with a corresponding series of unwelded pieces. Each test piece shall be 24 in. in length by 3 in. in breadth, the breadth to be reduced to 2 in. for a distance of 6 in. on each side of the center. The surface of the welded joints must be machined so that the thickness of the specimen in way of the weld is not greater than that of the plain plate. The average tensile strength of the welded joints thus measured must not be less than 90 per cent that of the unwelded plate.

In addition to the above, two specimens 20 in. in breadth and ½ in. in thickness, with transverse butt weld, must be made, suitable for testing in a 300 ton machine. In this case the surface of the welding need not be trimmed but may be left slightly above that of the adjacent plating to the extent that would be adopted in actual practice. Small test pieces must be cut from the plain plate to determine its tensile strength. The ten-

*Issued by the Secretary of Lloyd's Register of Shipping on Oct. 11th, 1920.

sile strength of the above butt welds should be about 90 per cent, of that of the plain plate.

8. Modulus of Elasticity. In order to permit the modulus of elasticity of the deposited material to be determined, two specimens shall be prepared from pieces of mild steel 25 in. in length, 3 in. in breadth, and ½ in. in thickness, by cutting out a central rectangle about 13 in. long and 1¼ in. wide, and filling this space with deposited material. These specimens to be machined to the usual test piece form, leaving a central portion, about 1 in. in width, of deposited material only.

9. Alternating Strodd Test. A flat plate, ¾ in. in thickness, and 3 ft. in length, to be cut through at a distance of 9 in. from one end, and the two pieces butt welded together. The plate to be then cut into longitudinal strips, 15 in number, ¾ in. in breadth, and these strips turned into round bars.

The bar to be tested will be fixed in a lathe running at about 1,000 revolutions per minute, and will be so loaded that a uniform bending moment is applied to that portion of the bar containing the weld. The loads to be adjusted so that for different bars the stress applied will vary from 12 tons per square inch to 6 tons per square inch, and the number of revolutions at which the bars break under each stress to be noted in order that a graph may be drawn.

At an applied stress of + 6 tons per square inch the welded bars must be able to withstand approximately 5,000,000 revolutions.

10. Impact Test. Two specimens, ¼ in. and ½ in. in thickness respectively, to be prepared of dimensions 5 ft. 0 in. x 2 ft. 6 in., having a butt weld in the centre parallel to the shorter edge.

The plates to be arranged on supports, spaced 4 ft. 6 in. apart, placed parallel to the short edges of the plate and raised about 18 in. from the ground. The specimens should be able to sustain two successive blows from a falling weight as detailed below, without showing any sign of fracture of the weld:—

Thickness of Plate	Weight to be Dropped	Height from which weight to be dropped
¼ in.	2 cwt.	9 feet
½ in.	4 cwt.	12 feet

11. The Committee may require, in any particular case, such additional tests as may be considered necessary.

State Rules

Arkansas

REGULATIONS relating to the application of a welding process to boiler work are under the jurisdiction of the Bureau of Labor and Statistics, State Boiler Inspector, Little Rock, Ark. The A. S. M. E. Code, (1918 Edition) is in force.

California

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the Industrial Accident Commission of the State, San Francisco, Cal. The A. S. M. E. Code (1918 Edition) is in force. In the construction of air tanks 28,500 pounds tensile strength is required, flange steel or better being required in construction, except where the thickness is below ¼ inch.

Illinois

There are no State rules governing the application of a welding process to boiler work. In the City of Chicago the so called "Chicago Code" is enforced. These rules are nothing more nor less than the 1918 A. S. M. E. Code, and they are not rigidly enforced.

Indiana

Under the date of September 10th, 1920, the Chief Deputy Boiler Inspector, Indianapolis, Ind., stated: "the use of oxy-acetylene or electric arc may be used when the weld is not subject to a tensile strain. The welding of tubes in all boilers by this process is not permitted."

Maryland

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of The State of Maryland Board of Boiler Rules, Baltimore, Md. The A. S. M. E. Code (1918 Edition) is in force.

Michigan

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the Board of Boiler Rules, Lansing, Mich. J. C. McCabe, Chief Inspector (City Service Bldg., Detroit, Mich.) said on September 15th, 1920: "Oxy-Acetylene or electric arc welding is not allowed in any place where there is a tension load on the joint. Generally speaking, such methods of welding are not approved. Forge welding, however, is approved for general use subject to proper inspection and test."

Minnesota

The Chief of State Boiler Inspector states (Sept. 10th, 1920) that the State is "endeavoring to enforce the Boiler Code of the American Society of Mechanical Engineers." Methods disapproved by the A. S. M. E. are disapproved by the State. Regulations relating to such matters are under the jurisdiction of the Chief State Boiler Inspector, St. Paul, Minn.

Nebraska

There are no rules relating to boiler welding in this State. The Nebraska Inspection Bureau, Omaha, Neb., an organization affiliated with insurance companies, recommends the rules and regulations of the Underwriters' Laboratories, and these rules and regulations will be found in this Section.

New York

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the State Industrial Commission, Albany, N. Y.

Industrial Code

186 **Welded Joints.** The ultimate strength of a joint which has been properly welded by the forging process, shall be taken as 28,500 lbs. per sq. in., with steel plates having a range in tensile strength of 45,000 to 55,000 lb. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld

209 The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except when the stays, are welded and have a larger cross-sectional area at the weld than at some other point, in which case the strength at the weld shall

be computed as well as in the solid part and the lower value used.

Note: Paragraphs 186 and 209 are from the A. S. M. E. Code (1918 Edition).

Recommendations for Repairs When Made By Welding and Reinforcing by the Electric, Oxy-Acetylene, or Other Processes

From General Rules and Regulations Prescribed by the Steam Boiler and Fly-Wheel Service Bureau

By "autogenous welding" is meant any form of welding by fusion, that is, where the metal of the parts to be joined or added metal used for the purpose is melted and flowed together to form the weld. Such welding is accomplished by the oxy-acetylene, hydrogen or other flame processes, or by the electric arc; no distinction is made between any of those processes. The general rule to govern the acceptance of such welds in insured vessels is that prescribed by the Boiler Code of the American Society of Mechanical Engineers, Par. 186, as follows:

"Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code, and where the safety of the structure is not dependent upon the strength of the welds."

The following illustrations will serve to point out where such work should be accepted or rejected:

1. Any autogenous weld of reasonable length will be permitted in a staybolted surface or one adequately stayed by other means, so that should the weld fail the parts would be held together by the stays. It is necessary for the inspector to use judgment in interpreting the meaning of "reasonable length" as given above, since it may vary in different cases. In the average case it should be not more than 3 ft. Autogenous welding will not be accepted in unsupported surfaces.

2. The edges of the inner and outer sheets of vertical firebox boiler or boilers of the locomotive type may be joined by autogenous welding to form the door openings, if the surrounding surfaces are thoroughly stayed. This would also apply to other openings of a similar character in such surfaces.

3. For low pressure steel boilers operated at a pressure not exceeding 15 lbs. to the square inch, or for higher pressures in unfired vessels subjected to water pressure only, rectangular headers may be autogenously welded at the edges if the sheets are properly held together by stays. Autogenous welding of cracks and fractures in cast iron boilers will not be permitted.

4. Fire cracks in girth seams extending from the edge of the plate to the rivet hole may be autogenously welded provided the cracks are properly prepared by cutting out the metal at the crack in the form of a letter "V" to permit fusion through the entire thickness of the plates. Similar cracks in girth seams located between the rivet holes may also be autogenously welded, provided the cracks do not extend beyond the edge of the lap of the inner plate. In the latter class of cracks it is advisable to drill a hole not exceeding ⅜ in. in diameter at the end of the crack before the weld is made. Cracks extending from rivet hole to rivet hole on girth seams cannot be welded. Calking edges of girth seams may be built up by autogenous welding under the following conditions. The original section of the metal between rivet holes and calking edge to be built up must average equivalent to one-fourth of the diameter of the rivet hole and the portion of the calking edge to be replaced must not exceed 30 in. in length in a girthwise direction. In all repairs to girth seams by autogenous welding the rivets must be removed over the portions to be welded and for a distance of at least 6 in. at each and beyond such portions. After repairs are made the rivet holes should be seamed before the rivets are redriven.

5. Stayed sheets which have corroded to a depth of not more than 40 per cent of their original thickness may be reinforced or built up by autogenous welding. In such cases the stays shall come completely through the reinforcing metal so as to be plainly visible to the inspector.

6. Where tubes enter flat surfaces and the tube sheets have been corroded or where cracks exist between the tube ligaments, autogenous welding may be used to reinforce or repair such defects. The ends of such tubes may be autogenously welded to the tube sheets. The above-mentioned repairs for tube sheets and the welding in of tubes in the sheets are not to be permitted where such sheets form the shell of a drum or boiler such as in the case of Stirling type of boiler.

7. When external corrosion has reduced the thickness of plate around handholes to not more than 50 per cent of the original thickness and for a distance not exceeding 2 inches from the edge of the hole, the plate may be built up by autogenous welding.

8. Pipe lines will be accepted where the flanges or other connections have been welded autogenously, provided the work has been performed by a reputable manufacturer and the parts properly annealed before being placed in position. Such welding when made with the part in place and un-annealed will not be acceptable.

9. Autogenous welding in patches in the shell of a boiler will not be acceptable regardless of the size of such patches. Autogenous welding of cracks in the shell of a boiler—except those specified in Par. 4—regardless of the direction in which they may lie will not be permitted, unless such welding is only for the purpose of securing tightness and the stresses on the parts is fully cared for by properly riveted-on patches or straps placed over the weld. The plates at the ends of joints may be welded together for tightness provided the straps or other construction is ample to care for the stresses on the parts so welded.

10 Re-ending or piecing of tubes for either fire tube or water tube boilers by the autogenous process will not be permitted.

Ohio

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the Industrial Commission of Ohio, Division of Boiler Inspection, Columbus, Ohio.

Supplement No. 1, to Ohio Boiler Inspection Law, 1918 Edition:

AUTOGENOUS WELDING

By "autogenous welding" is meant any form of welding by fusion, that is where the metal of the parts to be joined or added metal used for the purpose is melted and flowed together to form the weld. Such welding is accomplished by the oxy-acetylene, hydrogen or other flame processes, or by the electric arc; no distinction is made between any of these processes.

Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the Rules formulated by the Ohio Board of Boiler Rules, and where the safety of the structure is not dependent upon the strength of the welds.

The following illustrations will serve to point out where such work should be accepted or rejected:

1. Any autogenous weld of reasonable length will be permitted in a staybolted surface or one adequately stayed by other means so that, should the weld fail, the parts would be held together by the stays. It is necessary for the inspector to use judgment in interpreting the meaning of "reasonable length" as given above, since it may vary in different cases. In the average case it should

not be more than 3 feet. Autogenous welding will not be accepted in unsupported surface.

2. The edges of the inner and outer sheets of vertical firebox boilers, or boilers of the locomotive type, may be joined by autogenous welding to form the door openings, if the surrounding surfaces are thoroughly stayed. This would also apply to other openings of a similar character in such surfaces.

3. For low-pressure plate-steel boilers operated at a pressure not exceeding 15 lb. to the sq. in., or for higher pressures in unfired vessels subjected to water pressure only, rectangular headers may be autogenously welded at the edges if the sheets are properly held together by stays. Autogenous welding of cracks and fractures in cast-iron boilers will not be permitted.

5. Stayed sheets which have corroded to a depth of not more than 40 per cent of their original thickness, may be reinforced or built up by autogenous welding. In such cases the stays shall come completely through the reinforcing metal so as to be plainly visible to the inspector.

6. Where the tubes enter flat surfaces and the tube sheets have been corroded or where cracks exist between the tube ligaments, autogenous welding may be used to reinforce or repair such defects. The ends of such tubes may be autogenously welded to the tube sheets. The above mentioned repairs for tube sheets and the welding in of tubes in the sheets, are not to be permitted where such sheets form the the shell of a drum or boiler, as in the case of the Stirling type of boiler.

7. When external corrosion has reduced the thickness of plate around handholes to not more than 50 per cent of the original thickness and for a distance not exceeding 2 in. from the edge of the hole, the plate may be built up by autogenous welding.

8. Pipe lines will be accepted where the flanges or other connections have been welded autogenously, provided the work has been performed by a reputable manufacturer and the parts properly annealed before being placed in position. Such welding when made with the part in place and unannealed will not be acceptable.

9. Autogenous welded-in patches in the shell of a boiler will not be acceptable regardless of the size of such patches. Autogenous welding of cracks in the shell of a boiler (except those specified in Par. 4) regardless of the direction in which they may lie will not be permitted, unless such welding is only for the purpose of securing tightness and the stresses on the parts are fully cared for by properly riveted-on patches or straps placed over the weld. The plates at the ends of the joints may be welded together for tightness, providing the straps or other construction are ample to care for the stresses on the parts so welded.

10. Re-ending or piecing of tubes for either fire-tube or water-tube boilers by the autogenous process will not be permitted.

Pennsylvania

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of Department of Labor and Industry, Harrisburg, Pa.

Safety Standards of the Industrial Board

Par. 209 The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except that when the stays are welded and have a larger cross-sectional area at the weld than at some other point, in which case the strength at the weld shall be computed as well as in the solid part and the lower value used.

Par. 186 **Welded Joints.** The ultimate strength of a joint which has been properly welded by the forging process, shall be taken as 28,500 lb. per sq. in., with steel plates having a range in tensile strength of 47,000 to 55,000 lb. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

Rhode Island

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the Boiler Inspection Department, State of Rhode Island, Providence, R. I. The 1918 Edition of the A. S. M. E. Code has been adopted.

Utah

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the Industrial Commission of Utah, Salt Lake City, Utah, The A. S. M. E. Code (1918 Edition) is in force.

Wisconsin

Regulations relating to the application of a welding process to boiler work are under the jurisdiction of the Industrial Commission of Wisconsin, Madison, Wis.

Code of Boiler Rules

Par. 4343 A longitudinal joint when properly welded by a forging process shall be assumed to have an ultimate tensile strength of 28,500 pounds for steel plates having a range in tensile strength of 47,000 to 55,000 pounds.

Welding by electric or acetylene gas process may be used on parts not subject to tensile strain.

Other States

States not mentioned as having rules and regulations in force are not known to have enacted laws. Several states, however, are understood to be contemplating the adoption of the A. S. M. E. Code, with a view to adopting the latest code which will probably be published in 1921.

Interstate Commerce Commission

Specifications for Shipping Containers

SHIPPING CONTAINER SPECIFICATION NO. 8

(See par. 1822 (a).)

Cylinders for the Shipment of Acetylene Gas
Effective October 1, 1914.

Material

1. Cylinders purchased hereafter and used for the shipment of acetylene gas must comply with the following specifications. Such cylinders purchased between April 1, 1912, and the effective date of the specifications must comply with the specifications approved by the Bureau of Explosives, effective April 1, 1912, or with these specifications.

2. (a) Cylinders must be made of basic, open-hearth steel.

(b) Chemical analysis:

	Per cent.
Carbon	0.06 to 0.20
Phosphorus (not to exceed)	0 04
Sulphur (not to exceed)	0.05

The chemical analysis must be verified by check analysis made on samples taken from one out of each order or lot of 200 or less plates, shells, or tubes from which the cylinders are to be made; provided, that one analysis of any one heat of steel is sufficient.

Inspection of Material

3. All plates, shells, or tubes from which cylinders are to be made must be carefully inspected before being made up into cylinders, and those which show cracks, laminations, or other defects must be rejected.

Annealing

4. All seamless cylinders must be uniformly and properly annealed.

All steel from which cylinders (not seamless) are to be made must be uniformly and properly annealed after any hot or cold drawing process or after any cold-rolling process. If not drawn or cold rolled it must be capable of bending on itself cold, without cracking.

Physical Test

5. The material from which the cylinders are made must have an elastic limit of not more than 45,000 pounds per square inch. This must be verified by check tests on specimens cut from one out of each order or lot of 200 or less of the plates, tubes, shells or finished cylinders. If the material has been hot or cold drawn or cold rolled, these tests must be made after the final annealing required by paragraph 4.

Openings for Connections

6. The length of thread for connections, such as valves, fuse plugs, gauge, etc., must be equal to the standard lengths specified for different sizes of pipe thread tappings.

Standard taper pipe threads must be employed on all threading for connections to cylinder, and these connections must be tapped to gauge with clean-cut threads, so as to insure tight joints.

Proctection of Connections

7. When a cylinder to contain inflammable gas is not to be boxed or crated for shipment (except as provided in paragraph 1863 (b), the safety and discharge valves and other connections must be made safe from injury during transit: (1) By being set into a recess of the cylinder so that it will be impossible for them to be struck if the cylinder is dropped on a flat surface; or (2) by a cap or collar, fastened to the cylinder (not to the valve or connection), this cap or collar to be capable of withstanding a blow delivered in any direction, of a 30-pound weight falling four feet, and constructed so that this blow will not be transmitted to the valve or connection; or (3) by such construction of the valves and connections that they will withstand four successive blows delivered by a weight of 30 pounds falling four feet, these blows to strike at right angles to the axis of valve or connection, and at points 90 degrees apart, without any leak developing; provided, that there is any point or part of the valve or connection which is relatively weak or whose injury by a blow would be liable to cause leakage, then one of the above-mentioned blows must be struck on that point and no leak must result. During the test indicated in (3) above, the cylinder must contain compressed air or gas under a pressure of at least 50 pounds per square inch. The blows of the weight must strike as nearly at the end of the valve or connection as may be possible, and the absence of leakage after the test is completed must be verified by application of soapsuds or by other suitable method.

Filling

8. The porous filling employed in these cylinders must be thoroughly dried before being placed in the cylinder, must show a porosity of between 75 per cent and 80 per cent, and must be assembled so as to leave no voids within the cylinder. In the event of a filling being used which is poured into the cylinder, and dried therein, such filling must be absolutely free from water or voids before the cylinder is put into service.

The filling must possess such structure as to render impossible any disintegration or sagging when wet with the solvent.

It must not be possible to explode a charged cylinder by locally applied heat.

Maximum Permitted Charging Pressure

9. The maximum permitted charging pressure must not exceed 250 pounds per square inch corresponding to a temperature of 70 degrees F.

Marking

10. Each cylinder must be plainly marked by etching or stamping on the shell or by a name plate soldered on the shell, such marking to indicate serial number of cylinder, compliance with these specifications, and the maximum permitted charging pressure at 70 degrees F., as follows:

No.....
Complies with I. C. C. Specification No. 8
Maximum Permitted Pressure.....
Lbs. at 70 Degrees F.

If desired, the words "Complies with I. C. C. Specification No. 8" may be abbreviated to "I. C. C.—8."

The date of manufacture must also be plainly stamped on the cylinder. (For example 4-13 for April 1913).

When offered for shipment the package must also bear such other description as may be required by the I. C. C. Regulations for the particular article contained therein.

Standard Pressure Test

11. One completed cylinder selected at random out of every lot of 200 or less must be subjected to a hydrostatic test in a water jacket, or other apparatus of suitable form, to furnish reliable data, to an official test pressure of not less than three times the maximum permitted charging pressure per square inch, corresponding to a temperature of 70 degrees F. The permanent volumetric expansion must not exceed 10 per cent of the total volumetric expansion at this pressure.

No pressure in excess of 100 pounds per square inch shall be applied to the cylinder previous to this test, except that a pressure of 100 pounds less than the official test pressure may be applied once previous to the official test for the purpose of rounding out the cylinder.

In the hydrostatic test the water gauge indicating the expansion must be of such interior diameter that the total expansion will cause the water to rise at least 45 centimeters in the gauge, except when this will make the interior diameter less than 4 millimeters; the pressure must be applied for not less than 30 seconds and as much longer as may be necessary to insure complete expansion of the cylinder. The expansion must be recorded in terms of cubic centimeters.

If this cylinder fails to pass this test, two others from the same lot may be selected at random, and these two must pass the test in order to have the lot accepted.

If the lot of cylinders is rejected, under the above test, the manufacturer may have the privilege of testing each of the remaining cylinders of the lot in the manner indicated above, and those cylinders which pass the test may be accepted.

Service Pressure Test

12. Each completed cylinder, after being packed with filling and before being put into service, must be subjected to a uniform pressure of not less than two times the maximum permitted charging pressure per square inch corresponding to a temperature of 70 degrees F., and they must not show any defect under this test.

Inspection

13. The purchaser must provide for the inspection of all material and all tests by a competent inspector, and a report must be made, as provided in paragraph 16, of this specification, to the chief inspector of the Bureau of Explosives, 30 Vesey Street, New York City.

Cylinders Now in Service

14. Cylinders now in service must fulfill the requirements of Section 8 of these specifications, must be tested before December 31, 1914, to a pressure of at least two times the maximum permitted charging pressure per square inch corresponding to a temperature of 70 degrees F. without showing any apparent defects and must be marked as prescribed by paragraph 1861 (i) of the I. C. C. Regulations. or if not so tested before December 31, 1914, they must then not be shipped after December 31, 1914, until they have been so tested.

Exemption From Quinquennial Test

15. New cylinders that have been manufactured, tested and reported as prescribed herein, and cylinders now in service that have been tested as prescribed by section 14, need not be tested quinquennially (paragraph 1861 (e) of the I. C. C. Regulations).

Forms For Reports

16. The report required by paragraph 13 must be submitted in the following form:

(Place).....
(Date).....

Report of inspection of.....cylinders, ...inches O. D. by.....inches long, numbered from.....to....., inclusive.
Manufactured by the.....Company.
Inspected for the.....Company.

These cylinders were manufactured as follows.[1]

The steel from which these cylinders were manufactured complies with the requirements of paragraphs 2 and 5 of specification No. 8 as to chemical analysis and physical characteristics, as will be observed from the certificate of the manufacturer of the steel attached hereto.[2]

A sample was selected at random from the steel used in the manufacture of each order or lot of 200 or less of these cylinders and a check chemical analysis was made. The report thereof is attached hereto.

A sample was selected at random from each order or lot of 200 or less of the [3](plates)—(tubes)—(shells)—(finished cylinders) and a check physical test was made. The report thereof is attached hereto.

The [3](plates)—(tubes)—(shells) from which these cylinders were manufactured were inspected by..... and those which were accepted were found free from seams cracks, laminations, or any defects which might prove injurious to the strength of the cylinder.

The walls were measured with a pair of calipers and the minimum thickness of wall noted was.....

One cylinder out of each lot of 200 or less was selected at random and was subjected to a hydrostatic pressure of.....pounds per square inch, in the presence of the inspector. A rounding out pressure of..... pounds per square inch [3](was)—(was not) applied. The record of these tests is attached hereto.

Each and every cylinder was subjected to a hydrostatic pressure of.....pounds per square inch and showed no defect.

Each and every cylinder has been completely filled with.....in the form of ..... The porosity of the filling is between 75 per cent and 80 per cent as determined from tests made at random.

Each and every cylinder is marked with the date of manufacture and with the wording required by paragraph 10 of Specification No. 8.

I hereby certify that these cylinders proved satisfactory in every way and comply with the requirements of the Interstate Commerce Commission Specification No. 8 and with paragraph 1822 (a) of the Interstate Commerce Commission Regulations.

.....Inspector.

[1]State as to whether seamless, or seamless body with heads brazed in, or brazed throughout, or welded throughout, etc., etc.

[2]This certificate may be in any form, but must include a complete definite statement as to the requirements which the steel complies with.

[3]Draw a line through the words not required.

SHIPPING CONTAINER SPECIFICATION NO. 3

(See par. 1822 (a).)

Cylinders for the Shipment of Carbonic Acid Gas, Nitrous Oxide Gas, Blaugas, and Any Liquefied Gas Whose Charging Pressure At 70 Degrees F. Exceeds 300 Pounds Per Square Inch

NOTE.—These cylinders may also be used for nonliquefied gases where charging pressure at 70 degrees F. does not exceed 1,800 pounds per square inch, though Specification No. 3A is especially applicable to such cylinders.

Revised July 2, 1914
Effective October 1, 1914.

1. Cylinders purchased hereafter and used for the shipment of carbonic acid gas, nitrous oxide gas, blaugas, or any liquefied gas whose charging pressure at 70 degrees F. exceeds 300 pounds per square inch must comply with the following specifications. Such cylinders purchased between March 31, 1912, and the effective date of these specifications must comply with the specifications effective March 31, 1912, or with these specifications.

2. Cylinders must be made seamless, of steel of uniform quality.

Chemical Analysis

3.

	Per Cent.
Carbon must not exceed	0.55
Phosphorus must not exceed	0.04
Sulphur must not exceed	0.05

Annealing

4 All cylinders after finishing must be uniformly and properly annealed. All dirt and scale must be removed from both inside and outside of the cylinders.

Flattening Test

5. From each lot of 200 or less a representative finished cylinder, after annealing and after having passed the hydrostatic test, must be selected at random and must withstand, without cracking, flattening between rounded knife-edges to a thickness of six times the thickness of the wall of the cylinder, this measurement to be made between the outside surfaces of the walls of the cylinder.

Provided, That when, on account of the small number of cylinders in any lot or order, it is impracticable to make the regular crushing test herein prescribed, the physical and crushing test may, in cases of lots not to exceed thirty cylinders each, be made on a ring not less than eight inches long, cut from each cylinder, and subjected to the same annealing and other heat treatment as the finished cylinder.

The knife edges must be of wedge shape, converging at an angle of 60 degrees, the point being rounded off with a radius of ½ inch. If any one cylinder from any lot fails to pass this test, two others from the same lot must be selected, and these must pass it in order to have the lot accepted.

If it should appear that failure in the test is due to improper annealing, the manufacturer has the privilege of reannealing the lot and repeating the test.

Physical Tests

6. One out of each lot of two hundred or less finished cylinders after annealing must be selected at random and tests made on test specimens cut longitudinally therefrom to determine the elastic limit, the tensile strength, and the elongation of the material. These test specimens should, when practicable, be taken from the same cylinders which are used for the flattening test.

The elongation must be not less than 10 per cent on an 8-inch test specimen.

The elastic limit must not be more than 70 per cent of the tensile strength.

Hydrostatic Test

7. Each finished and annealed cylinder must be subjected to a hydrostatic test of not less than 3,000 pounds per square inch in a water jacket, or other apparatus of suitable form, to furnish reliable data. The permanent volumetric expansion must not exceed 10 per cent of the whole volumetric expansion at this pressure.

This test must be made without subjecting the cylinder to any previous internal pressure in excess of 1,000 pounds.

In the hydrostatic test the water gauge indicating the expansion must be of such interior diameter that the total expansion will cause the water to rise at least 45 centimeters in the gauge, except when this will make the interior diameter less than 4 millimeters; the pressure must be applied for not less than 30 seconds and as much longer as may be necessary to insure complete expansion of the cylinder. The expansion must be recorded in terms of cubic centimeters.

Marking

8. Each cylinder must be plainly and permanently marked on the shoulder with a serial number and with the name or initials of the original purchaser.

9. Each cylinder must also be plainly and permanently marked on the shoulder with the words "COMPLIES WITH I. C. C. SPEC'N No. 3," or, if desired by the purchaser, this may be abbreviated to "I. C. C. —3." This marking must be placed immediately above the serial number and in letters not less than ¼ inch high.

10. The date of the hydrostatic test must also be stamped on the cylinder (for example 4-09 for April, 1909) in such manner that the dates of the subsequent quinquennial tests required by paragraph 1861 (i) may be easily added thereto.

General Construction

11. All billets, plates, or tubes from which cylinders are made must be free from seams, cracks, laminations, or any defects which might be injurious to the finished cylinder.

12. The manufacture of the cylinders must be completed with the best appliances and according to the best modern methods. All finished cylinders must show reasonably smooth and uniform surface finish, inspection of inside surface to be made before necking down; the threading of the cylinder neck must be even and without checks, and the cylinders must show no defects of workmanship or material likely to result in any appreciable weakness of the finished cylinder. A close inspection of each completed cylinder must be made before acceptance to discover any defect.

Inspection

13. The purchaser must provide for inspection of all material and all tests by a competent and disinterested inspector.

14. The inspector must keep complete records of the various melts from which the steel is taken for the manufacture of the cylinders. Certified chemical analyses of these melts must be supplied to him by the manufacturer, or, if desired by the purchaser, he must procure samples from each melt from which other chemical analyses may be made. The heat number must be stamped on the plates and billets at the steel mill, and the inspector must also stamp his initials or personal sign on each plate or billet accepted by him, and no plate or billet must be used for the manufacture of cylinders unless so marked.

Provided, that when cylinders are to be made from drawn seamless tubing under conditions such that the various heats of steel can not be properly traced through to the finished cylinders, a certificate from the manufacturer of the tubing (see note at end of report, par. 19, for form of certificate), together with check analyses of samples taken from one out of each lot of 200 or less finished cylinders. shall be accepted.

15. The inspector shall make such inspection as may be necessary to see that the requirements of paragraphs 11 and 12 are complied with, shall see that the finished cylinders are properly annealed, and shall witness all hydrostatic and flattening tests.

The hydrostatic and flattening tests must be made by the manufacturer, but under the direction and supervision of the inspector or other representative of the purchaser.

16. The inspector shall stamp his initials or his personal sign immediately beneath the serial number on each cylinder which he passes as accepted and shall make a certified report (see par. 19) to the maker, to the purchaser, and to the chief inspector, Bureau of Explosives, 30 Vesey Street, New York City, showing the serial numbers of all cylinders which are accepted, together with a copy of all data relating to the material and the tests.

Exemptions for Cylinders of Small Dimensions

17. (a) Cylinders and other containers which have an outside diameter of less than 2 inches and a length of less than 2 feet shall be accepted without complying with the requirements of paragraphs 5, 6, 7, 8, 9, 10, 13, 14, 15, 16, and 19 of this specification under the following conditions; provided, that cylinders having an outside diameter not greater than ⅞ inch and a capacity of not more than 4 fluid ounces are not subject to specifications.

(b) All such containers of whatever size or shape shall be considered and known as cylinders.

(c) From each lot of 500 or less a representative finished cylinder must be selected at random and subjected to hydrostatic pressure until it bursts. The bursting pressure must be noted in the report required by paragraph 17 (f), and must not be less than 6,000 pounds per square inch.

(d) Each cylinder must be subjected to a

hydrostatic pressure of not less than 3,000 pounds per square inch without showing any apparent effect.

(e) Each cylinder must be plainly and permanently marked as follows:

X-XX—I. C. C.—3

the X's to be replaced by a date showing month and year of manufacture (for example 5-13 to indicate May, 1913).

(f) A report on all cylinders placed in service, giving complete data and certifying that all requirements of this specification have been complied with, must be made to the chief inspector, Bureau of Explosives, 30 Vesey Street, New York City. This report may be rendered by the manufacturer instead of by an outside inspector.

Additional Requirements

18. The purchasers of cylinders may impose additional requirements not inconsistent with these specifications.

Reports

19. The report required by paragraph 16 must be submitted in the following form:

(Place) .....
(Date) .....

Report of inspection of.....cylinders numbered from.....to..... inclusive
Manufactured by the.....company
Inspected for the..... company

[1]The steel from which these cylinders were manufactured was made by the.....company. Chemical analyses were made from samples representing each melt of steel, as it will be observed from the report of chemical test hereto attached.

The [2](plates)—(tubes) from which these cylinders were manufactured were inspected by....., and those which were accepted were found free from seams, cracks, laminations, or any defects which might prove injurious to the strength of the cylinder.

Each and every cylinder before [2](necking down)—(closing) was inspected inside and outside for surface defects. The thickness of walls was measured at points not more than 8 inches from the open end of the cylinder with a pair of calipers and the minimum thickness of wall noted was.....

Each and every cylinder was [2](necked down)—(closed) and was uniformly and properly annealed, and then the cylinders were again inspected in order to discover any defects which might have been caused by this process.

One out of each lot of 200 or less finished cylinders was selected by the inspector and subjected in his presence to a flattening test as required by the Interstate Commerce Commission specifications. All of the cylinders passed this test satisfactorily.

Two longitudinal test pieces were cut from each crushed cylinder and pulled.

The record of the physical and flattening tests is attached hereto.

Each and every cylinder was subjected to a hydrostatic test of not less than 3,000 pounds in the presence of the inspector. The record of the hydrostatic tests is attached hereto.

Each and every cylinder was stamped with the initials.....of the purchasing company and with the date of test.

Each and every cylinder was stamped on the shoulder with a serial number.

Each and every cylinder was stamped with the personal sign.....of the inspector immediately beneath the serial number of the cylinder.

[3]Each and every cylinder was plainly stamped.....just above the serial number.

I hereby certify that all of these cylinders proved satisfactory in every way and comply with the requirements of the Interstate Commerce Commission Specification No. 3 and with paragraph 1822a of the Interstate Commerce Commission Regulations.

.....
Inspector.

[1]If the cylinders are made from drawn seamless tubing under such conditions that it is impossible to trace the various heats of steel through to the finished cylinder (see par. 14), this paragraph should be replaced by the following:

The tubing from which these cylinders were manufactured was made by the..... company under orders No. ....., and their certificate stating that its chemical composition complies with the requirements is attached hereto. Check analyses were made from samples representing each lot of 200 or less cylinders, as will be observed from the report of chemical tests attached hereto.

Also, the report must be accompanied by a certificate from the manufacturer of the tubing, as follows:

(Place) .....
(Date) .....

This is to certify that the tubing furnished to the.....Company on orders No..... does not contain more than 0.55 per cent of carbon, nor more than 0.04 per cent of phosphorus, nor more than 0.05 per cent of sulphur.

.....
(Signature of manufacturer of tubing.)

This form to be used only when cylinders are made from drawn seamless tubing. (See par. 14.)

[2]Draw a line through word not required.

[3]Insert marking used. See paragraph 9.

SHIPPING CONTAINER SPECIFICATION NO. 3A.

(See par. 1822 (a).)

Steel Cylinders for the Shipment of Nonliquefied Gases Whose Charging Pressures at 70° F. Exceed 300 Pounds Per Square Inch

Effective October 1, 1914

Note.—If these cylinders are manufactured and marked for a charging pressure of 1,800 pounds per square inch (see par. 9) they may also be used for liquefied gases, though specification No. 3 is especially applicable to such cylinders.

---

1. Cylinders purchased hereafter and used for the shipment of nonliquefied gases whose charging pressures at 70° F. exceed 300 pounds per square inch must comply with the following specifications. Such cylinders purchased between March 31, 1912, and the effective date of these specifications must comply with the specifications effective March 31, 1912, or with these specifications.

2. Cylinders must be made seamless, of steel of uniform quality.

Chemical Analysis

3.

	Per cent
Carbon must not exceed	0.55
Phosphorus must not exceed	0.04
Sulphur must not exceed	0.05

Annealing

4. All cylinders after finishing must be uniformly and properly annealed. All dirt and scale must be removed from both inside and outside of the cylinders.

Flattening Test

5. From each lot of 200 or less a representative finished cylinder, after annealing and after having passed the hydrostatic test, must be selected at random and must withstand, without cracking, flattening between rounded knife-edges to a thickness of six times the thickness of the wall of the cylinder, this measurement to be made between the outside surfaces of the walls of the cylinder.

Provided, That when, on account of the small number of cylinders in any lot or order, it is impracticable to make the regular crushing test herein prescribed, the physical and crushing test may, in cases of lots not to exceed thirty cylinders each, be made on a ring not less than eight inches long, cut from each cylinder, and subjected to the same annealing and other heat treatment as the finished cylinder.

The knife-edges must be of wedge shape,

converging at an angle of 60°, the point being rounded off with a radius of ½ inch. If any one cylinder from any lot fails to pass this test, two others from the same lot must be selected, and these must pass it in order to have the lot accepted.

If it should appear that failure in the test is due to improper annealing, the manufacturer has the privilege of reannealing the lot and repeating the test.

Physical Tests

6. One out of each lot of two hundred or less finished cylinders after annealing must be selected at random and tests made on test specimens cut longitudinally therefrom to determine the elastic limit, the tensile strength, and the elongation of the material. These test specimens should, when practicable, be taken from the same cylinders which are used for the flattening test.

The elongation must be not less than 10 per cent on an 8-inch test specimen.

The elastic limit must not be more than 70 per cent of the tensile strength.

Hydrostatic Test

7. Each finished and annealed cylinder must be subjected to a hydrostatic test in a water jacket, or other apparatus of suitable form, to furnish reliable data. The test pressure must be not less than 1⅔ times the charging pressure corresponding to a temperature of 70° F. for which the cylinder is designed, except that the minimum allowable test pressure shall be 600 pounds per square inch. The permanent volumetric expansion must not exceed 10 per cent of the whole volumetric expansion at this pressure.

This test must be made without subjecting the cylinder to any previous internal pressure in excess of one-third of the test pressure.

In the hydrostatic test the water gauge indicating the expansion must be of such interior diameter that the total expansion will cause the water to rise at least 45 centimeters in the gauge, except when this will make the interior diameter less than 4 millimeters; the pressure must be applied for not less than 30 seconds and as much longer as may be necessary to insure complete expansion of the cylinder. The expansion must be recorded in terms of cubic centimeters.

Marking

8. Each cylinder must be plainly and permanently marked on the shoulder with a serial number and with the name or initials of the original purchaser.

9. Each cylinder must also be plainly and permanently marked with the words "COMPLIES WITH I. C. C. SPEC'N No. 3A***," or, if desired by the purchaser, this may be abbreviated to "I. C. C.—3A ***." The stars to be replaced by figures indicating the charging pressure for which the cylinder is designed which will be not more than three-fifths of the pressure used in the test prescribed by paragraph 7. This marking must be placed immediately above the serial number and in letters not less than ¼ inch high.

10. The date of the hydrostatic test must also be stamped on the cylinder (for example, 4-09 for April, 1909) in such manner that the dates of subsequent quinquennial tests required by paragraph 1861 (i) may be easily added thereto.

General Construction

11. All billets, plates, or tubes from which cylinders are made must be free from seams, cracks, laminations, or any defects which might be injurious to the finished cylinder.

12. The manufacture of the cylinders must be completed with the best appliances and according to the best modern methods. All finished cylinders must show reasonably smooth and uniform surface finish, inspection of inside surface to be made before necking down; the threading of the cylinder neck must be even and without checks and the cylinders must show no defects of workmanship or material likely to result in any appreciable weakness of the finished cylinder. A close inspection of each completed cylinder must be made before acceptance to discover any defect.

Inspection

13. The purchaser must provide for inspection of all material and all tests by a competent and disinterested inspector.

14. The inspector must keep complete records of the various melts from which the steel is taken for the manufacture of the cylinders. Certified chemical analyses of these melts must be supplied to him by the manufacturer, or, if desired by the purchaser, he must procure samples from each melt from which other chemical analysis may be made. The heat number must be stamped on the plates and billets at the steel mill and the inspector must also stamp his initials or personal sign on each plate or billet accepted by him, and no plate or billet must be used for the manufacture of cylinders unless so marked, provided, that when cylinders are to be made from drawn seamless tubing under conditions such that the various heats of steel can not be properly traced through to the finished cylinders a certificate from the manufacturer of the tubing (see note at end of report, par. 19, for form of certificate), together with check analyses of samples taken from one out of each lot of 200 or less finished cylinders, shall be accepted.

15. The inspector shall make such inspection as may be necessary to see that the requirements of paragraphs 11 and 12 are complied with, shall see that the finished cylinders are properly annealed, and shall witness all hydrostatic and flattening tests.

The hydrostatic and flattening tests must be made by the manufacturer, but under the direction and supervision of the inspector or other representative of the purchaser.

16. The inspector shall stamp his initials or his personal sign immediately beneath the serial number on each cylinder which he passes as accepted, and shall make a certified report (see par. 19) to the maker, to the purchaser, and to the chief inspector, Bureau of Explosives, 30 Vesey Street, New York City, showing the serial numbers of all cylinders which are accepted, together with a copy of all data relating to the material and the tests.

Exemptions for Cylinders of Small Dimensions

17. (a) Cylinders and other containers which have an outside diameter of less than 2 inches and a length of less than 2 feet shall be accepted without complying with the requirements of paragraphs 5, 6, 7, 8, 9, 10, 13, 14, 15, 16, and 19 of this specification under the following conditions; provided, that cylinders having outside diameters not greater than ⅞ inch and capacity of not more than 4 fluid ounces are not subject to specifications.

(b) All such containers of whatever size or shape, shall be considered and known as cylinders.

(c) From each lot of 500 or less a representative finished cylinder must be selected at random and subjected to hydrostatic pressure until it bursts. The bursting pressure must be noted in the report required by paragraph 17 (f), and must be not less than 6,000 pounds per square inch.

(d) Each cylinder must be subjected to a hydrostatic pressure of not less than 3,000 pounds per square inch without showing any apparent defect.

(e) Each cylinder must be plainly and permanently marked, as follows:

X—XX—I. C. C.—3 A.

the X's to be replaced by a date showing month and year of manufacture (for example, 5-13 to indicate May, 1913).

(f) A report on all cylinders placed in service, giving complete data and certifying

that all requirements of this specification have been complied with, must be made to the chief inspector, Bureau of Explosives, 30 Vesey Street, New York City. This report may be rendered by the manufacturer instead of by an outside inspector.

Additional Requirements

18. The purchasers of cylinders may impose additional requirements not inconsistent with these specifications.

Reports

19. The report required by paragraph 16 must be submitted in the following form:

(Plate) .....
(Date) .....

Report of inspection of.....cylinders numbered.....to....., inclusive
Manufactured by the.....Company
Inspected for the.....Company

[1]The steel from which these cylinders were manufactured was made by the.....Company. Chemical analyses were made from samples representing each melt of steel, as will be observed from the report of chemical test h reto attached.

The [2](plates)—(tubes) from which these cylinders were manufactured were inspected by....., and those which were accepted were found free from seams, cracks, laminations, or any defects which might prove injurious to the strength of the cylinder.

Each and every cylinder before [2](necking down)—(closing) was inspected inside and outside for surface defects. The thickness of walls was measured at points not more than 8 inches from the open end of the cylinder with a pair of calipers, and the minimum thickness of wall noted was.....

Each and every cylinder was [2](necked down)—(closed) and was uniformly and properly annealed and then the cylinders were again inspected in order to discover any defects which might have been caused by this process.

One out of each lot of 200 or less finished cylinders was selected by the inspector and subjected in his presence to a flattening test as required by the Interstate Commerce Commission specifications. All of the cylinders passed this test satisfactorily.

Two longitudinal test pieces were cut from each crushed cylinder and pulled.

The record of the physical and flattening tests is attached hereto.

Each and every cylinder was subjected to a hydrostatic test of.....pounds in the presence of the inspector. The record of the hydrostatic tests is attached hereto.

Each and every cylinder was stamped with the initials.....of the purchasing company and with the date of test.

Each and every cylinder was stamped on the shoulder with a serial number.

Each and every cylinder was stamped with the personal sign.....of the inspector immediately beneath the serial number of the cylinder.

[3]Each and every cylinder was plainly stamped.....just above the serial number.

I hereby certify that all these cylinders proved satisfactory in every way and comply with the requirements of the Interstate Commerce Commission Specification No. 3A and with paragraph 1822 (a) of the Interstate Commerce Commission Regulations.

.....,
Inspector.

[1]If the cylinders are made from drawn seamless tubing under such conditions that it is impossible to trace the various heats of steel through to the finished cylinder (see par. 14), this paragraph should be replaced by the following:

The tubing from which these cylinders were manufactured was made by the.....Company under orders No. ....., and their certificate stating that its chemical composition complies with the requirements is attached hereto. Check analyses were made from samples representing each lot of 200 or less cylinders, as will be observed from the report of chemical tests attached hereto.

Also, the report must be accompanied by a certificate from the manufacturer of the tubing as follows:

(Place).....
(Date).....

This is to certify that the tubing furnished to the.....Company on order No.....does not contain more than 0.55 per cent of carbon, nor more than 0.04 per cent of phosphorus, nor more than 0.05 per cent of sulphur.

.....
(Signature of Mfr. of tubing.)

This form to be used only when cylinders are made from drawn seamless tubing. (See par. 14.)

[2]Draw a line through word not required.

[3]Insert marking used. (See par. 9.)

American Railroad Association (M. C. B.)

Code of Rules

SECTION 3 (Mechanical)—By letter ballot, approved certain additions to the Rules of Interchange, which have also been approved by the American Railroad Association at its session held November 19, 1919. **These rules become effective March 1, 1920, unless otherwise noted.**

In addition to the changes in the rules as result of approval of recommendations of committees by letter ballot, there are several additional rules and modifications of rules, prepared by the Arbitration Committee, which have been approved by the Executive Committee of the American Railroad Association.

For Cars Having Steel Center Sill Splices Located at Least 7 Inches from Face of Bolster

Adjacent sills may be spliced.

All splices shall be of the butt-joint type, reinforced on both sides by plates of not over 24 inches in length, and not less than twice the length of the protruding end when the projection is less than 12 inches. The reinforcing plates shall be at least as thick as the web of the sill. The splice plate on the flange side of the sill shall be U-shaped, to include flanges, while the plate on the opposite side shall cover the web only.

* * * *

Where autogenous welding is available, the sills may be welded after riveting the U-shaped plate on the flange side, omitting the flat plate on web side.

For Cars Having Steel Center Sill Splices Located Between Body Bolster and End Sill, and Less Than 8 Inches from Face of Bolster

flanged over the bottom leg of the side sill, and riveted to the same, as shown in Fig. 14. The splice may be located on either side of the body bolster.

The rivets shall be spaced as shown.

Side sills may also be welded by the autogenous process, making the thickness of the metal through well one and one-half times the thickness of the metal in the sill, in which case the reinforcing plates and rivets shown in Fig. 14 may be omitted.

Rule 23.—A new rule governing welding of

parts of cars is provided, reading as follows:

Autogenous welding, by either gas or electric process, when performed must be strictly in accordance with the following limits and regulations.

Coupler bodies, knuckles, knuckle pins, locks, lifters and throwers.

Parts made of alloy steel or heat treated carbon steel. Top chord angles of open top all-steel cars if the fracture is located at a

A should be slightly greater than diameter of pencil

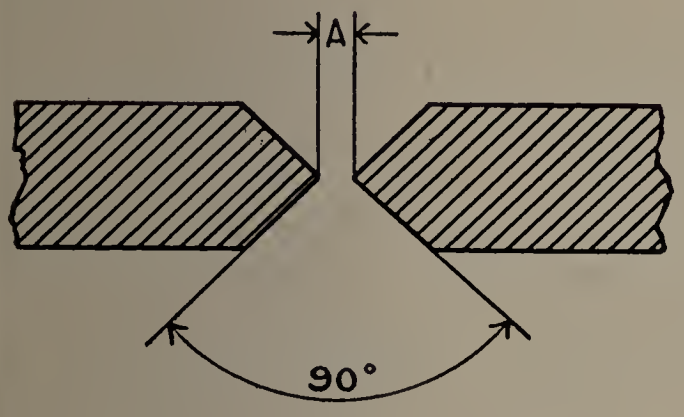


FIG. 1

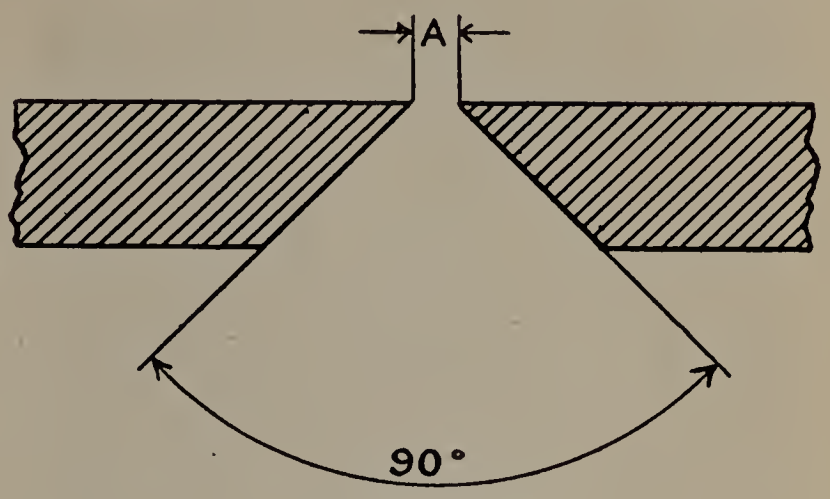


FIG. 2

Autogenous Welding Limits and Regulations

I. General.—In welding, either by the use of gas or electricity, care and good judgment on the part of the operator are of prime importance. The operator's ability as to the desired proficiency should be certified by the mechanical officers in charge or by an instructor qualified by experience in general railroad welding with the method involved.

point between bolsters more than 5 feet from the center line of either body bolster.

III. Building up worn surfaces will be permissible on the following:

Parts subject to compression only.
*Spring or bolster hangers.
*Holes in levers.
†Center plates.
†Truck sides, bolsters and column castings.
Journal boxes.

When piece is subject to high tension B must be more than 1½ T

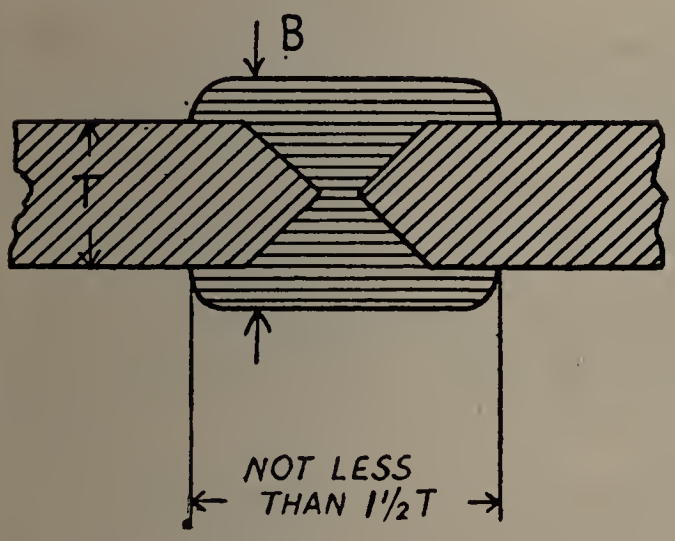


FIG. 3

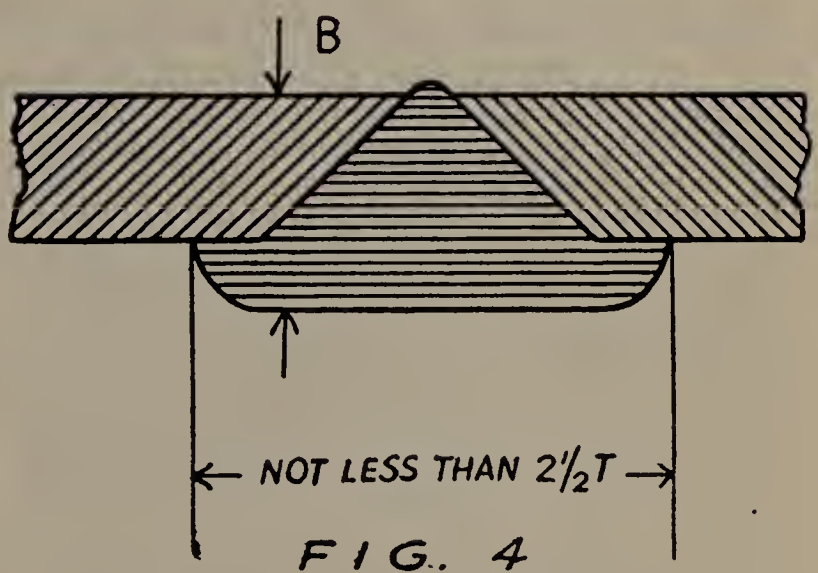


FIG. 4

The metal added is liable to be porous and relatively brittle.

The heat at the surfaces welded affects other sections near the weld, tending to reduce strength and toughness.

The following general rules must, therefore, be carefully observed:

II. Welding cracks or fractures will not be permitted on the following:

Axles.
Arch bars.
Car wheels or tires.
Grab irons.
Truck equalizers.
Sill steps.
Spring or bolster hangers.
Brake staffs.
Brake wheels.

*Provided that the material remaining in part is equal to at least 80 per cent of the original section.

†Provided that the material remaining in part is equal to 60 per cent of the original section.

Coupler bodies, knuckles, locks, lifters and throwers. After building up the original section, the same must be dressed and then checked with proper gauges to insure interchangeability and proper operation.

IV. Welding cracks or fractures will be permitted on the following:

Parts subject to compression only, and general car parts not subject to high tension strains, except as otherwise prohibited.

Car and roof sheets.
*Cast steel truck sides.

*Pressed and structural steel truck sides, bolsters and transoms.
*Cast steel bolsters.
Draft castings.
*Brake beams.
*Cast steel coupler yokes.
Car sills, posts, braces, stakes, carlines, side plates and end plates.

*Welding is permitted only when the area of the crack is less than two-fifths, or 40 per cent. of the total area through the section at thepoint of fracture, but it is not permissible to weld any crack located within 6 inches of an old weld

V. Regulations for Welding:

(a) All parts marked (*) in Section IV., except truck transoms, must not be welded unless removed from car or truck. Truck transoms may be welded in place by removing the truck from under car body.

(b) The edges of pieces for welding must be prepared as shown in Figs. 1 and 2. If both sides of the fractured member can be worked upon the fracture should be prepared as per Fig. 1, and where only one side of the fractured member is accessible Fig. 2 should be followed. The entire crack should be burned or chipped out far enough back so that there will be no portion of the crack in the metal. Failure to do this permits the check or crack to work its way across the metal to the farther side, due to the constant vibration, even after the weld has been made. A hole may be drilled at the end of crack or check and chip or burn towards the pole. The surfaces where new material is to be deposited must be clean and bright and reasonably smooth, and, therefore, if the surfaces are prepared by the burning process the surfaces must be finished by chipping before welding

(c) The portion of the part adjacent to the fracture should be heated before the welding is begun. In welding, the operator should begin to weld at the point farthest away from the outside edge and work the weld towards the edge. All efforts must be made to prevent oxidizations, and to accomplish this the work should be placed at an angle that will allow the blowing out of all slag or impurities in the fused metal, and by giving the torch a rotary movement it will assist in their removal.

(d) The new material must be deposited to the forms shown in Figs 3 or 4 in order to properly reinforce the weld, and "B" should be somewhat greater than "T." For the important items marked (*) in Section IV., as well as for car sills, posts, braces, stakes, carlines, side plates and end plates, "B" must be at least one and one-half times "T."

(e) The parts marked (*) in Sections III and IV. with the exception of truck transoms welded in place, must be carefully annealed by uniformly heating to approximately 1,400 or 1,500 degrees Fahrenheit and allowed to cool slowly in the atmosphere

(f) Worn surfaces permitted to be built up to the original section by depositing of new metal thereon must first be made clean, bright and fairly smooth, and, after the metal is deposited, must be dressed to the required dimensions and gauged where necessary.

(g) When truck side frames and bolsters are welded the weld must be made smooth and the following record legibly stamped on the weld by at least ⅜ inch steel stencils, in the following form:

(Mo.-Day-Yr.)	(Railroad)
o — o — o	A. B C.
XY	X
(Shop abbreviation mark.)	(Welder's identification number or mark.)

Steam Boiler and Fly Wheel Service Bureau

Requirements for Autogenous Welding in Insured Boilers or Other Pressure Vessels for New Construction or Repairs*

BY "autogenous welding" is meant any form of welding by fusion, that is, where the metal of the parts to be joined or added metal used for the purpose is melted and flowed together to form the weld. Such welding is accomplished by the oxy-acetylene, hydrogen or other flame processes, or by the electric arc; no distinction is made between any of these processes. The general rule to govern the acceptance of such welds in insured vessels is that prescribed by the Boiler Code of the American Society of Mechanical Engineers, Par. 186, as follows:

"Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code, and where the safety of the structure is not dependent upon the strength of the welds."

The following illustrations will serve to point out where such work, should be accepted or rejected:

1. Any autogenous weld of reasonable length will be permitted in a staybolted surface or one adequately stayed by other means so that should the weld fail, the parts would be held together by stays. It is necessary for the inspector to use judgment in interpreting the meaning of "reasonable length," as given above, since it may vary in different cases. In the average case, it should be not more than 3 feet. Autogenous welding will not be accepted in unsupported surface.

2. The edges of the inner and outer sheets of vertical firebox boilers or boilers of the locomotive type may be joined by autogenous welding to form the door openings, if the surrounding surfaces are thoroughly stayed. This would also apply to other openings of a similar character in such surfaces.

3. For low pressure plate steel boilers operated at a pressure not exceeding 15 pounds to the square inch, or for higher pressures in unfired vessels subjected to water pressure only, rectangular headers may be autogenously welded at the edges if the sheets are properly held together by stays. Autogenous welding of cracks and fractures in cast iron boilers will not be permitted.

4. Fire cracks in girth seams extending from the edge of the plate to the rivet hole may be autogenously welded, providing the cracks are properly prepared by cutting out the metal at the crack in the form of a letter "V" to permit fusion through the entire thickness of the plates. Similar cracks in girth seams located between the rivet holes may also be autogenously welded, provided the cracks do not extend beyond the edge of the lap of the inner plate. In the latter class of cracks it is advisable to drill a hole not exceeding ⅜ inch in diameter at

This Bureau serves as a guide for all Insurance companies doing boiler and pressure vessel insurance business.

the end of the crack before the weld is made. Cracks extending from rivet hole to rivet hole on girth seams cannot be welded. Calking edges of girth seams may be built up by autogenous welding under the following conditions: The original section of the metal between rivet holes and calking edge to be built up must average equivalent to one-fourth of the diameter of the rivet hole and the portion of calking edge to be replaced must not exceed 30 inches in length in a girthwise direction. In all repairs to girth seams by autogenous welding the rivets must be removed over the portions to be welded and for a distance of at least 6 inches at each and beyond such portions. After repairs are made the rivet holes should be seamed before the rivets are redriven.

5. Stayed sheets which have corroded to a depth of not more than 40 per cent of their original thickness, may be reinforced or built up by autogenous welding. In such cases the stays shall come completely through the reinforcing metal so as to be plainly visible to the inspector.

6. Where tubes enter flat surfaces and the tube sheets have been corroded or where cracks exist between the tube ligaments, autogenous welding may be used to reinforce or repair such defects. The ends of such tubes may be autogenously welded to the tube sheets. The above-mentioned repairs for tube sheets and the welding in of tubes in the sheets are not to be permitted where such sheets form the shell of a drum or boiler such as in the case of Stirling type of boiler.

7. When external corrosion has reduced the thickness of plate around handholes to not more than 50 per cent of the original thickness and for a distance not exceeding 2 inches from the edge of the hole, the plate may be built up by autogenous welding.

8. Pipe lines will be accepted where the flanges or other connections have been welded autogenously, provided the work has been performed by a reputable manufacturer and the parts properly annealed before being placed in position. Such welding when made with the part in place and un-annealed will not be acceptable.

9. Autongenous welded in patches in the shell of a boiler will not be acceptable, regardless of the size of such patches. Autogenous welding of cracks in the shell of a boiler—except those specified in Par. 4—regardless of the direction in which they may lie will not be permitted, unless such welding is only for the purpose of securing tightness and the stresses on the parts is fully cared for by properly riveted-on patches or straps placed over the weld. The plates at the ends of joints may be welded together for tightness, provided the straps or other construction is ample to care for the stresses on the parts so welded.

10. Re-ending or piecing of tubes for either fire tube or water tube boilers by the autogenous process will not be permitted.

Underwriters' Laboratories

Standards for Construction of Stationary Acetylene Generators, Pressure Regulators; Blow Pipes and Fittings for Oxy-Acetylene Welding and Cutting Systems

INTRODUCTION

OXY-ACETYLENE welding and cutting systems are equipments for utilizing oxygen and acetylene in manufacturing processes where high temperatures are required. A system consists of an acetylene and an oxygen supply, piping, regulators, hose, torches or blow pipes and flash back checks.

For the purpose of identifying the principal systems the following classification is given in which the classes are arranged with regard to pressures. The parts mentioned in each class are arranged in approximately the order of their installation in the systems.

Class A, Low Pressure Systems:

Stationary low pressure acetylene generators for pressures not to exceed one pound per square inch; flash back check; oxygen supply; oxygen regulators; hose and torches or blow pipes.

Class B, Medium Pressure Systems:

(1) Stationary medium pressure acetylene generator for pressures not to exceed fifteen pounds per square inch; flash back check; oxygen supply; oxygen and acetylene regulators; hose and torches or blow pipes.

(2) Stationary low pressure acetylene generator (Class A) for pressures not to exceed one pound; flash back check; standard mechanical compressor for pressures not to exceed fifteen pounds per square inch; oxygen supply; oxygen and acetylene regulators; hose and torches or blow pipes.

**These specifications constitute an outline of the requirements for the construction of acetylene generators, for inside installation; flash back checks; pressure regulators and blow pipes.*

Class C, High Pressure Systems:

Systems for portable or stationary use consisting of standard acetylene storage cylinders for pressures not to exceed 250 pounds per square inch at temperatures of 70 degrees Fahr.; oxygen supply; oxygen and acetylene regulators; hose and torches or blow pipes.

These rules refer particularly to stationary welding and cutting outfits, and it is to be noted that portable outfits designed for generating acetylene or oxygen, or both when used inside buildings are regarded as much more hazardous than stationary generators and introduce features which cannot be brought into compliance with the rules for stationary apparatus.

Where portable apparatus is required inside of buildings the use of standard storage tanks for both acetylene and oxygen, mounted on a substantial truck is recommended.

NOTE—The use of liquid acetylene, or gas generated therefrom, or any system of generation of acetylene under a pressure in excess of fifteen (15) pounds per square inch is absolutely prohibited.

DEFINITIONS*

Acetylene Generator—A machine for producing acetylene from calcium carbide. The machine consists of a carbide holder, feed mechanism, generating chamber and storage space for a limited quantity of gas.

Flask-Back—A term used in these specifications to cover any form of local explosion or decomposition which may be transmitted through the hose, regulators and piping to other parts of the system. Other terms

**For Definitions covering "Generators," "Flash Back," etc., see these terms in Index Section.—Ed.*

such as "flare-back", "snap-back", "back-flash", and the like.

Flash-Back Check—A term used to describe a device or fitting designed to protect the larger gas storage space in the system against explosions due to flash-backs. This fitting is sometimes called a "back-flash preventor", or a "hydraulic back pressure valve". This fitting may be made in two sizes; one having sufficient capacity to be installed in the main acetylene supply line close to the generator and the other of smaller capacity to be installed in the piping system at the blow pipe connection. The small individual flash-back check may be required on systems for the purpose of more completely localizing any flash-back and avoiding disturbance of the complete system by the faulty operation of one blow pipe.

Regulator—A valve or fitting, generally of the diaphragm type, for controlling the flow of gas and maintaining a steady pressure at the blow-pipe. This valve is also referred to as a reducing valve, owing to the fact that it is generally used to reduce a comparatively high pressure to the proper pressures for welding or cutting. Regulators are made in various sizes and for wide ranges of service. Acetylene generators are frequently provided with a master regulator on the service line and in addition to this, smaller regulators are made for each blow-pipe. Regulators are frequently referred to by terms indicating the service for which they are designed as welding regulators, cutting regulators, oxygen regulators and acetylene regulators.

Blow-Pipe—A device used to combine acetylene and oxygen in proper proportions to produce the high temperatures required for welding and cutting processes. This device is frequently termed a torch and is made in different forms for welding and for cutting and in combination for welding or cutting.

Gallon—The word gallon as used in these specifications refers to the U. S. gallon of 231 cubic inches.

Gauges, Metal—Sheet metal is specified in U. S. Standard Gauge for Sheet Metal.

SPECIFICATIONS

CLASSES A AND B—ACETYLENE GENERATORS

The specifications immediately following apply to both low-pressure and medium-pressure acetylene generators.

NOTE—General practice for house-lighting acetylene generators to be followed where applicable, particularly for Class "A."

1. **Rating and Marking:**

(a) Generators to be of sufficient capacity to furnish gas up to the maximum rating under working conditions, from one charge of carbide, for at least one working period of four hours. For carbide-feed machines for this service the rating may properly be one cubic foot of gas per hour, per pound of carbide, whereas with the usual water-feed machines the rating should not be more than one-half the above.

NOTE—The carbide capacity when filled according to directions is taken as the basis for the rating. (See Rule 6b.)

(b) Every machine to be plainly marked with the maximum number of cubic feet of gas it is designed to supply per hour, the amount and size of carbide necessary for a single charge, the Manufacturer's name and address, and the trade name or designating marking of the machine.

NOTE—Complete charging and operating directions must accompany each generator to the user.

2. **Operation:**

Generators to be automatically regulated and uniform in action, producing gas as far as practicable only as immediate consumption demands, and so designed that gas is generated without producing sufficient heat to cause excessive yellow discoloration of residuum (which will occur at about 500 degrees Fahr.) or abnormal pressure at any stage of the process when using carbide of the proper grade and when operating under full or 150 percent load.

NOTE—The presence of excessive heat tends to change the chemical character of the gas and may even cause danger, while in machines of the carbide-feed type finely divided carbide will produce excessive pressure unless provision is made to guard against it. (See also Rule 7d.)

3. **Metal:**

(a) Metal parts to be made of iron or steel as far as practicable, and in a manner and of materials to insure durability. Copper and its compounds in contact with acetylene are to be avoided; but brass, containing a comparatively low percentage of copper may be used in stuffing-boxes, cocks, bearings etc.

NOTE—Iron or steel sheet metal and castings should be coated to prevent corrosion. This is preferably to be done by hot galvanizing or equivalent process. Brass parts in contact with acetylene preferably to be tinned or coated with solder. Where sheet-metal coating is injured in fabrication it should be recoated. This may be done with solder. Welded joints should be recoated with solder on the inside and preferably on the outside also. If not practicable to coat the outside a suitable paint may be used. A rust-resisting asphaltum-linseed oil paint or the equivalent is recommended for the outside of the shell.

(b) The thicknesses of sheet metal to be based on the diameters of the various parts and the service to which they may be subjected.

NOTE—The weights of metal given in the following specifications are minimum requirements and large sizes and special designs will usually require heavier metal. Sheet-metal is specified in United States Standard Gauge for Sheet-Metal and variations up to 2.5 percent below the nominal gauge may be permitted.

(c) Joints to be of such nature that parts will not be separated as a result of heating. Sheet-metal joints to be lock-seamed or riveted and thoroughly sweated with solder, or made by some method which will give equivalent service.

NOTE—This is intended to prevent the use of wood and of joints relying entirely upon solder.

(d) Castings to be formed to fit the contour of the shell as far as practicable.

4. **Assembly:**

(a) Machines to be assembled in a substantial and workmanlike manner to insure stability and durability.

(b) Parts, including piping, attached to the machine to be thoroughly braced in place, and the whole machine to be protected against injury during transportation.

NOTE—It is recommended that machines of 50-pound size and smaller be shipped as units, where practicable, and that braces be provided on larger machines to properly locate the generating chamber, the gas holder and other parts in assembling so as to prevent undue stresses on connections of piping to sheet metal.

(c) Bottoms of shells not to rest directly on the foundation, and to be reinforced or protected when necessary to insure sufficient strength.

NOTE.—This is to protect the bottom against corrosion, puncturing from objects on the foundation, and undue stresses.

(d) To be arranged so as to insure correct procedure in recharging and cleaning.

NOTE—This requires various interference arrangements called for in different parts of these specifications.

(e) To be so arranged that feeding of carbide will be automatically prevented while recharging with carbide.

NOTE—This is to prevent dangerous escape of gas. It is also recommended that feeding be prevented before draining the generating chamber or adding water to it.

(f) All water seals to be maintained at the regular level under all conditions, irrespective of use of water for generating purposes.

(g) No valves or pet cocks to be used, the opening of which into the room from the gas-holding parts, or parts which if drained, will allow the escape of gas.

NOTE—Such valves and pet-cocks are not essential; their presence increases the possibility of leakage.

(h) Gauge glasses, the breakage of which would allow the escape of gas, not to be used.

(i) The construction to be such that liquid seals will not become thickened by the deposit of lime or other foreign matter.

(j) The apparatus to be constructed so that accidental hazardous siphoning of water will be impossible.

(k) Flexible tubing, swing pipe joints, springs, mechanical check valves, chains, pulleys, and lead or fusible piping not to be used on acetylene apparatus, except where failure of such parts will not affect the safety of the machine or permit, either directly or indirectly, the escape of gas into the room. Floats not to be used, excepting in cases where failure to operate will result only in rendering the machine inoperative.

5. Generating Chamber.

(a) Generating chambers in machines which apply water to the carbide should be arranged so that not more than 5 pounds of carbide can be acted upon at once in any single compartment.

NOTE—This tends to reduce the danger of overheating and excessive after-generation by providing for division of the carbide charges in machines of this type.

(b) To be so constructed that the amount of carbide acted upon at one time is small enough to prevent overheating and excessive after-generation. under any load up to 50 percent in excess of the rated capacity.

(c) The water capacity of the generating chamber of machines of the carbide-feed type shall be such that not less than one gallon of water is provided for each pound of carbide which can be introduced into the carbide holder.

NOTE—The carbide capacity for this purpose is taken as the entire space in the holder which might be occupied by carbide. (See Rule 6b.)

(d) To be provided with suitable vent connection to the blow-off pipe, so that residuum may be removed and the generating water replaced without causing siphoning or introducing air in any considerable quantity to the gas holder upon recharging.

(e) The water or carbide supply to the generating chamber to be so arranged that gas will be generated long enough in advance of the exhaustion of the supply already in the gas-holder to allow the continuous use of the full rated load without exhausting such supply.

NOTE—This provides for the continuous working of the apparatus under all conditions of feed, and water and carbide charge; and it obviates the failure of the gas supply through intermittent action of the machine.

(f) To be provided with a cover having a secure fastening to hold it in place. The cover should be amply strong to withstand the pressure in the generator, as well as the stresses of clamping or bolting it in place.

(g) To be so designed that the residuum will not clog or affect the working of the machine and can conveniently be handled and removed.

(h) The bottom of the generating chamber of machines of the carbide-feed type should be pitched so that the sludge will readily drain to the draw-off and an agitator should be provided to stir the residuum to facilitate its removal. The agitator should be substantially mounted and arranged so as not to injure the shell.

6. Carbide Holders:

(a) To contain sufficient carbide to supply the maximum rating of gas for the full working period.

NOTE—This rule is designed to avoid the necessity of recharging or attending to the machine at improper hours. There should be ample assurance of a sufficient quantity of gas to last for the working period; serious losses will occur should the supply of gas fail while work is in process. It is desirable that an indicator be provided, showing approximately the quantity of carbide remaining in the hopper at any time.

(b) Carbide holder to be of such design that when filled according to directions it will contain at least the rated capacity. The total amount of carbide that can be introduced into the holder to fill all available space must not exceed in number of pounds the number of gallons of water contained in the generating chamber. The fill opening to be so located and of such size that the total quantity of carbide for which the holder is designed can be conveniently introduced.

(c) To be so arranged that the charge of carbide may be removed in case of necessity.

NOTE—This is to reduce the spilling of carbide in dismantling for repairs or other reasons.

7. Feed Mechanism:

(a) The feed mechanism for machines of the carbide-feed type to be so designed that the direct fall of carbide from the carbide holder into the water of the generating chamber is prevented at all positions of the mechanism; or when actuated by the rise and fall of a gas bell, of the pressure in the generator, or of the water level of some part of the machine, to be so arranged that the feed mechanism remains inoperative as long as the filling opening on the carbide holder remains open.

(b) Feed mechanisms actuated by the rise and fall of a gas bell to be arranged so that feeding of carbide or water will be shut off before the gas bell reaches the landed position. The feed to be shut off when the bell is not less than 1½ inches from its landed position.

(c) The feed of carbide or water to be so controlled that under no conditions can more gas be generated than will be carried off by the safety reliefs without excessive rise of pressure.

(d) Feed mechanisms for machines of the carbide-feed type should not allow continuous run of commercial ¼ by 1/12-inch or larger carbide.

NOTE—It is very strongly recommended that a continuous run of even smaller carbide be made impossible. This is to prevent hazards due to use of very fine carbide if the proper size is not available, and to possible disintegration of the rated grade of carbide with production of very fine particles.

(e) The use of plug or similar type valves closing upward against the flow of carbide is recommended against on account of the possibility of becoming stuck in the open position due to foreign material or large pieces of carbide.

(f) The mechanism should always be far enough above the water level to avoid clogging from accumulation of lime. For this reason the feed mechanism should be not less than 10 inches above the highest water level.

8. Gas Holder:

Gas holder should be of sufficient capacity to contain all gas generated following operation with 50 percent over load and after the use of gas has been stopped.

NOTE—If the holder is too small and

blows off frequently after consumption of gas has ceased there is a waste of gas. This may suggest improper working of the apparatus and encourage tampering.

9. Piping:

(a) Standard full-weight galvanized wrought-iron or steel pipe to be used.

(b) Pipe connections may be made with right and left couplings; long-thread nipples with locknuts; or with unions of approved type which obviate the necessity for using gaskets.

(c) Pipe connections to sheet metal to be made with a substantial lock nut on each side of the sheet or through flanges riveted in place, the joint in either case to be thoroughly sweated with solder; or the connection should be made by some method which will give equivalent service. The pipes and the fittings in the machine to be galvanized, and where fittings are used as lock nuts they should be faced if not flat. Flanges, if riveted, should be secured by at least three rivets.

(d) Piping should drain to the condensation chamber as far as practicable.

(e) Piping to be clean and free from burrs.

10. Reliefs or Safety Blow-Off Connections:

(a) Relief pipes to be not less than ¾ inch internal diameter up to and including the 25-pound size, and to be provided with suitable means for connecting to a pipe leading outside the building. Greater relief capacity to be provided for larger machines.

NOTE—This means the inlet connection to any relief. The outlet should be at least as large as the inlet and preferably larger.

(b) Reliefs to be of such size as to comply with Rule 7c, and to be arranged so that they will not become clogged or stuck by accumulation of lime or other material and so that gas will have free access to them.

(c) The relief pipe should be arranged without traps and so that any condensation will drain back to the generator.

(d) Parts used in adjustment of pressure reliefs to be arranged so that tampering will be minimized.

11. Stuffing Boxes:

Stuffing boxes leading from gas-holding parts to the outside of the shell, if used, to be of the rotating shaft type or the equivalent. The standard stuffing box should have a separate unthreaded packing gland. The lower ends of the gland and the packing recess should be beveled at angles of about 30 to 40 degrees, and the gland should have a shoulder or other provision to facilitate removal. Adjustment by a threaded cap is preferred, and no packing should be in contact with threads. Equivalent construction for special conditions may be accepted.

12. Purifiers, Scrubbers and Filters:

(a) Where installed, should conform to the general rules for the construction of other acetylene apparatus and allow free passage of gas.

(b) When located on the discharge side of the flash-back preventor to be made of not less than No. 18 U. S. Standard gauge metal. A device of this kind when located between generator and flash back check not to be made of lighter than No. 22 U. S. gauge metal.

(c) To contain no carbide for drying purposes.

(d) When located outside of gas holder not to have hand holes which can be opened without first shutting off the gas supply, except where an interference arrangement is provided to assure the proper sequence of operations. When the outlet to the service line is connected to the cover plate of the filter no interference is required. When the cover is secured by 6 or more bolts the interference need not be as complete as when readily removable clamps or thumb screws are employed.

13. Gaskets and Diaphragms:

(a) Gaskets to be of a high-grade of rubber without insertion except where necessary for strength, as in diaphragms. In such cases a high-grade rubber gasket with cloth insertion may be used.

(b) Where joints are not frequently opened, as between bolted flanges, flat gaskets with flat seats may be used.

(c) Where joints are frequently opened, as on carbide filling openings, a round rubber gasket cemented in a groove and seating on a rounded ridge or equivalent construction is recommended. When only one surface, of the gasket or the casting, is rounded it should be the lower one so that carbide or other material will not be likely to lodge thereon and interfere with proper closure.

(d) Diaphragms to be backed or supported as far as practicable to prevent undue distention.

(e) All fittings using diaphragms, injury of which might allow escape of gas, except small individual regulators at the connections of blow-pipes or torches, should be enclosed with a housing vented to the outside of the building through a pipe sufficiently large to carry off all acetylene which may escape, due to leakage, rupture or other failure of the diaphragm. These vent connections should be made to the blow-off pipe on the machine itself at the factory. Regulators for individual blow-pipes or torches, while preferably piped as above may, when of small size, be left unconnected.

14. Air Mixtures:

Generators to be so arranged as to contain the minimum amount of air when first started or recharged, and no device or attachment facilitating or permitting mixture of air with the gas prior to consumption, except at the blow-pipes or torches, to be allowed.

NOTE—Some forms of generators for welding purposes may require somewhat greater internal capacity than house-lighting machines of similar size, but this should be cut down as far as practicable to approach the condition that all air mixtures should be expelled within 6 minutes after starting, on 150 percent load.

15. Pressure Regulators, Generator:

(a) To conform to the rules for the construction of other acetylene apparatus so far as they apply, and to avoid the possibility of sticking or clogging.

NOTE—Refer to Rule 28 for individual high or low pressure regulators for use at blow pipe connections. Expansion tanks or chambers not to be accepted in lieu of regulators.

(b) To be capable of maintaining the pressure within the limits required for proper operation of the generator for any load within its rating.

(c) To be installed with such valves as are necessary to facilitate inspection and repairs.

(d) Parts used in adjustment of regulators on generators to be arranged as far as practicable so that changes in the setting which permit pressures in excess of 15 pounds may not be made.

16. Flash-Back Check, Generator:

(a) A positive means should be provided for preventing the transmission of a flash in the piping to the generator. This appliance to be arranged to prevent the introduction of oxygen into the acetylene supply.

(b) To be of a hydraulic type or its equivalent and to be so arranged that it will be properly operative under all conditions of use.

(c) To be constructed of not less than No. 18 U. S. Standard gauge iron or steel, galvanized.

(d) To be arranged so as to facilitate filling to the proper level.

(e) Joints to be made mechanically secure by riveting or some equally efficient method.

(f) To be arranged so that accumulation

of pressure will be relieved through a connection to a separate blow-off to the outside air.

NOTE—This is necessary in order to prevent injury to the flash back check or other parts of the apparatus due to the high pressure of the oxygen. One or more flash-back checks may be connected to the same blow-off pipe, which should be distinct from the pipe connected with the pressure reliefs and the regulating valves in order to prevent transmission of a "flash back" to the generators through the generator relief pipe.

(g) To be arranged so that excessive amount of moisture will not be entrained by the issuing gas and carried away from the flash back check which would lower the water level.

SPECIFICATIONS ESPECIALLY APPLICABLE TO CLASS A (LOW-PRESSURE) ACETYLENE GENERATORS

In addition to the general rules for Class "A" and Class "B" machines the former type (Class "A") should be designed to conform to the following requirements:

17. Assembly:

(a) To be so arranged that during recharging back flow of gas from the gas-holder will be automatically prevented, or so arranged that it will be impossible to recharge the apparatus without first closing the supply pipe to the gas holder and to the other generating chambers, if several are used.

NOTE—This is intended to prevent the dangerous escape of gas.

(b) Condensation from all parts of the apparatus to be automatically removed without the use of valves or mechanical working parts.

NOTE—The automatic removal of condensation from the apparatus is essential to the safe working of the machine. U-traps opening into the room from the gas-holding parts not to be used for removal of condensation. All sealed drip connections to be so arranged as to discharge gas to the blow-off when blown out, and the seals should be self-restoring upon relief of abnormal pressure.

(c) All water seals should be so arranged that the water level may be readily seen and maintained.

18. Generating Chamber:

(a) Sheet metal in the generating chamber to be not less than No. 24 U. S. gauge (0.025 inch) in thickness for capacities up to and including 20 gallons; not less than No. 22 U. S. gauge (0.03125 inch) for capacities up to and including 75 gallons. Larger sizes in proportion.

(b) When the generating-chamber covers of machines of the water-feed type depend upon water seals the cover should be sealed to a depth at least 6 inches greater than the relief pressure (in inches water column). The seal shall not be less than 1½ inches wide and 9 inches deeper than the amount of the relief pressure, excepting those which depend upon the filling of the seal for the generation of gas, where 6 inches above the relief pressure will usually be sufficient.

(c) Generators should each be connected with the gas-holder in such a manner that they will, at all times, give connection either to the gas-holder or to the blow-off pipe to the outer air.

NOTE—This is to prevent dangerous pressure within or the escape of gas from the generating chamber.

19. Carbide Holder:

(a) To be constructed of galvanized iron or steel not less than No. 24 U. S. Standard gauge in thickness, for capacities up to and including fifty (50) pounds, and not less than No. 22 U. S. Standard gauge for capacities in excess of fifty (50) pounds.

(b) To be substantial, supported so as to resist vibration or other stresses which may be met in practice.

20. Gas Holder:

(a) To be constructed of galvanized iron or steel not less than No. 24 U. S. Standard gauge in thickness, for capacities up to and including 20 gallons; not less than No. 22 U. S. Standard gauge for capacities between 20 and 75 gallons; larger sizes in proportion. Condensation chambers, if placed under gas holders, to be of same gauge as the holders.

(b) Movable gas bells may be two gauges lighter than the requirement for the outer shell.

(c) The bell should move freely without tendency to bind and should have a clearance of at least ¾ inch around the outside.

NOTE—The clearance is to prevent binding due to distortion of the bell or the outer shell. Nothing except guides, if used, should project into the clear more than ⅜ inch. Guides attached to the gas bell, if used, should be set at the factory, and should be arranged so as not to injure the protective coating of the shell.

(d) The bell portion of a gas holder constructed on the gasometer principle should be provided with a substantial means for guiding its movement, carrying a stop to check the bell about one inch above the normal blow-off point.

(e) When constructed on the gasometer principle the gas holder should be so arranged that when the gas bell is filled to its maximum with gas at normal pressure its lip or lower edge will extend at least 9 inches below the inner water level.

(f) When constructed on the gasometer principle the dimensions of the tank portion should be so related to those of the bell and other parts that a pressure at least twice as great as the safety-relief pressure will be necessary before gas can be forced from the holder.

(g) The gas bell should be protected where feed rods or moving parts strike it and additionally reinforced or braced at the bottom when necessary. When weights are used they should preferably be attached near the bottom of the bell to increase the stability.

21. Reliefs or Safety Blow-Offs:

(a) In all cases to be provided, and to afford free vent to the outer air for any over-production of gas, and also afford relief in case of abnormal pressure in the machine.

NOTE—Both the above-mentioned vents may be connected with the same escape pipe. This rule refers to the so-called "Telescoping Blow-Off" or "Volume Relief" and the "Pressure Relief."

(b) To be constructed without valves or other mechanical working parts.

NOTE—Such additional complications are not necessary with the pressures involved.

22. Pressures:

(a) Apparatus not requiring a pressure regulator to be so constructed that the pressure will not vary more than one inch water column under all conditions of carbide charge and feed, and between the limits of no load and 50 percent overload.

NOTE—This means that the variation on any particular load should not exceed one inch at the generator outlet.

(b) Apparatus of this type should be so arranged that the gas pressure cannot exceed one pound per square inch.

SPECIFICATIONS ESPECIALLY APPLICABLE TO CLASS B (MEDIUM-PRESSURE) ACETYLENE GENERATORS

In addition to the general rules for Class "A" and Class "B" machines, the latter type (Class "B") should be designed to conform to the following requirements.

23. Assembly:

(a) Galvanized plates used to be of a thickness, depending upon the diameter of the cylinder to be formed, not less than specified in the following table:

Diameter	U. S. Standard
18 inches or less	No. 18 (0.050 inch)
24 inches or less	No. 16 (0.062 inch)
36 inches or less	No. 14 (0.078 inch)
48 inches or less	No. 12 (0.109 inch)

Parts having a diameter over 5 percent larger than mentioned above to be made of the next heavier plate. Plates not galvanized, if used, to be not less than $\frac{3}{16}$ inch in thickness.

(b) On account of the higher pressure used in this type of apparatus particular attention should be paid to the control of the temperature of generation so that any discoloration of residuum is prevented.

NOTE—The exposure of acetylene to temperatures as high as are indicated by the yellow discoloration of the residuum (about 500 degrees Fahr.) is liable to cause its explosive dissociation, if the acetylene is at a pressure in excess of 15 pounds gauge pressure per square inch.

(c) Condensation from all parts of the apparatus to be drained to such a point that the accumulation will not interfere with the passage of gas or the working of the machine.

NOTE—On account of the general construction of this type of generator there exists the possibility of the accumulation of condensation, but the working arrangement should be such that the free passage of gas is assured.

24. Reliefs or Safety Blow-Offs:

(a) Should preferably be constructed without valves or other working parts. Where valves or diaphragms are used the parts of the mechanism should be so arranged as to reduce as far as possible the chance of failure to release pressure; due to sticking of parts or failure of the diaphragm.

(b) Mechanical relief valves to be arranged so that they will be used as the vent valve or similarly operated as required by Rule 5d, whenever the generator is recharged. This is to insure proper operation of the safety relief and to prevent it from sticking.

25. Pressures:

(a) Apparatus of this type must be so arranged that the gas pressure will not exceed 15 pounds per square inch.

(b) Apparatus of this type should have a general regulator at the generator and preferably one for each blow-pipe connection. Pressures at generators should be regulated within the limits of the capacity of the individual regulator, under all conditions of general usage.

NOTE—Generators may be accepted without main regulators on the machine itself where the feed mechanism acts as a regulator. In such cases the pressure fluctuation when operating under full load should be not over 4 pounds per square inch. The use of a general regulator at the generator is very strongly recommended.

26. Air Mixtures:

The amount of air contained in the machine when first started or recharged is to be minimized as far as practicable.

27. Purifiers. Scrubbers and Filters:

To be constructed of galvanized iron or steel not less than No. 18 U. S. Standard gauge (0.05 inch) in thickness.

SPECIFICATIONS FOR INDIVIDUAL REGULATORS AND BLOW-PIPES OR TORCHES

28. Individual Regulators—High or Low Pressure:

(a) Must be of substantial construction and made of materials most suitable for the gases to be handled. Scrap metal must not be used for making castings and the design of the parts must be such as to best resist the stresses to which they are subjected. Seats of valve parts exposed to gases or high pressures or temperatures to be made of material especially adapted for the purpose.

(b) Must be capable of maintaining the pressure within the limits required for proper operation of the blow pipes at any load within the rating of the regulator.

(c) Parts subject to corrosion to be protected so far as practicable and possibility of sticking or clogging to be guarded against.

(d) Regulators to have bonnets so designed that in case of rupture of the diaphragm, free vent for the gases will be provided and the hazards of flying particles minimized.

(e) Pressure gauges must be so made as to prevent the throwing of glass or broken parts into the face of the operator.

(f) Union connections not requiring gaskets to be provided for hose connections and for attachment to high pressure cylinders.

(g) In the manufacture, shipment and use of regulators the possibility of introduction of dirt or any foreign substance must be guarded against.

(h) Regulators to be marked with the words "Acetylene" or "Oxygen" depending on the service for which they are designed. Marking must be cast, stamped or otherwise permanently made a part of the regulator or pressure gauges.

NOTE—Abbreviations Acet. and Ox. permissable where space is limited.

(i) Instructions giving complete operating directions and suggesting necessary precautions should be supplied with each regulator.

29. Blow-Pipes or Torches:

(a) Must be made so that they will not fall apart, become weakened or permit leakage when subjected to high temperatures in service.

(b) Must be made as substantial as is commensurate with the lightness necessary to permit easy handling of the device.

(c) The construction of the blow pipes or torches should be such that the mixing of the gases used will be accomplished in such a manner that the tendency to flash back will be reduced to a minimum.

(d) Controlling valves to be provided on each torch so that each gas supply can be properly regulated.

NOTE—Except use of fixed bench blocks for very small blow-pipes.

(e) Connectors for hose to be independent of gaskets for tightness and to be so arranged as to eliminate the necessity for removing hose clamps in disconnecting the hose from the torch.

(f) Hose connections on blow-pipes to be marked with the words "Acetylene" or "Oxygen" to identify the proper connection to make with the corresponding regulators.

NOTE—Abbreviations Acet. and Ox. permissible where space is limited.

National Board of Fire Underwriters

Regulations for the Installation and Operation of Acetylene Equipment

Recommended by the National Fire Protection Association.

APPLICATION OF RULES.

THE following regulations are intended to apply to the installation and operation of generators and the use of acetylene in and about buildings for lighting, welding, cutting and heating, including the storage of calcium carbide.

They do not apply to installation of systems involving a generator in or upon cars or other rolling stock or upon vessels. For such purposes, only properly safeguarded storage systems are permitted, except that standard flare lights or torches, with attached generators may be used if kept outside, so located as not to upset and so that escaping gas will not enter enclosures. For wrecking or emergency use, such portable lights may be used inside upon approval of the inspection department having jurisdiction, if under competent supervision. Storage of such portable generating apparatus shall not be in any room in which oper lights are used.

Note:—These regulations do not apply to plants devoted to the manufacture and compression of dissolved acetylene for sale.

Use of Standard Machines.

In the application of these regulations, it should be noted that only such acetylene generators and cylinders should be used as have been examined and tested and found to be safeguarded as far as possible. A list of such generators and cylinders is issued by Underwriters' Laboratories, Chicago, Ill., copies of which may be obtained upon application.

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GENERAL PRECAUTIONS.

1. General Precautions.

Failure to observe the following precautions and specifications will endanger life as well as property.

(a) Acetylene becomes an explosive compound under certain conditions and must be handled with care.

(b) Mixtures of acetylene and air are very explosive and must be carefully guarded against, and no device or attachment facilitating or permitting mixtures of air or oxygen with acetylene, prior to consumption, except at the burner, or in a standard torch or blow pipe, shall be allowed.

(c) Under no conditions must acetylene be subjected to more than 15 pounds pressure per square inch unless it is dissolved in acetone or other approved solvent and contained in a cylinder of the type described in Class E.

Self-compression generators which develop pressures above 15 pounds to the square inch are absolutely prohibited.

(d) The use of liquid acetylene or gas generated therefrom is absolutely prohibited.

(e) Tests of generators or piping for leaks must not be made with a flame and a flame must never be applied to an outlet from which the burner has been removed. Tests for leaks should be made with soapy water.

(f) Soldering irons should not be used on acetylene generators until it is certain that all gas has been removed. Soldering irons should never be used on acetylene cylinders under any conditions.

(g) The charging of the generator and the handling of the calcium carbide shall be by daylight only and no fire or artificial light other than incandescent electric vapor-proof lights shall be permitted within 10 feet of the generator unless separated therefrom by a brick or other non-combustible wall having no opening within 10 feet of said generator.

(h) Metal tools used for opening carbide containers or for making repairs must be used with caution to avoid striking a spark which may ignite a gas and air mixture, if present.

(i) Electrical apparatus, such as switches telephones, and other apparatus which may cause a spark, must not be located in any generating or gas-storage room. All electrical installation shall be in accordance with the National Electrical Code.

(j) No acetylene generator shall be moved by a crane or derrick while charged.

2. Approved and Marked Generators to Be Used.

Generators shall be of approved construction and shall be plainly marked with the maximum rate in cubic feet of acetylene per hour for which they are designed, the amount of carbide necessary for a single charge, the manufacturer's name and address and the name or number of the type of machine.

3. Storage of Calcium Carbide.

(a) Calcium carbide in quantities not to exceed six hundred (600) pounds may be stored, when contained in approved metal packages not to exceed one hundred (100) pounds each, inside of buildings provided that the place of storage be dry, waterproof and well ventilated, and also provided that all but one of the packages of each size of carbide shall be sealed and the seals shall not be broken so long as there is carbide in excess of one (1) pound in any other unsealed package in the building.

(b) It is recommended that the quantities of carbide permitted under paragraph (a) be stored in the generator room and not elsewhere unless a more suitable place can be provided.

(c) Calcium carbide in excess of six hundred (600) pounds shall be stored in approved metal packages above ground in one-story buildings without cellar or basement and used exclusively for the storage of calcium carbide, unless in a specially constructed outside generator house. Storage buildings shall be constructed to be dry, waterproof and well ventilated, and shall be located outside congested mercantile or manufacturing districts. If storage building is of incombustible construction, it may adjoin other one-story buildings if separated therefrom by an unpierced fire wall; if detached less than ten feet from such one-story buildings, there shall be no openings in the adjacent sides of either building. If the storage building is of combustible construction, it must not be within twenty feet of other one-story

or two-story buildings, nor within thirty feet of other buildings over two stories.

(d) Packages must be made of metal of sufficient strength to insure handling without rupture and must be provided with a screw top or its equivalent. They must be so constructed as to be water and air-tight without the use of solder, except at such points as it may be necessary to use this in order to close small crevices which cannot be otherwise sealed. Solder must not be used on joints in such a manner that fire would disrupt the package.

Packages containing calcium carbide must be conspicuously marked "Calcium Carbide —Dangerous if not kept dry."

PART 1.
USE OF ACETYLENE FOR LIGHTING.
CLASS A.
STATIONARY AUTOMATIC APPARATUS PERMITTED FOR INSIDE INSTALLATION.

4. Size of Generator.

The capacity of the generator shall be in terms of cubic feet of acetylene generated per hour, based on an allowance of one-half a cubic foot per hour per pound of carbide in the normal charge; the maximum number of lights shall not exceed the rated capacity of the generator divided by the indicated consumption of the burners, as marked on them.

The above allowance is based on a normal lighting period of nine hours for all burners installed, and a greater rating shall not be used, even though it seems probable that only a few lights will be used at a time; where lighting periods of greater length than this are necessary, the rating of the generator shall be based on a coresponding reduction in the allowance of one-half cubic foot per pound of carbide.

5. Maker's Instructions to Be Followed.

(a) When installing generators, the instruction card furnished by the maker shall be carefully read and its directions followed in every detail.

(b) Approved warnings and instruction cards provided by the maker shall be posted in a well lighted position near the generator so that the operator may consult them conveniently from time to time.

6. Location of Generators.

(a) While generators, especially in closely built up districts, should preferably be placed outside of buildings, in generator houses constructed and located in compliance with section 7, below, the installation of standard generators within buildings in accordance with the rules is permitted. However, it should be noted that the installation of acetylene generators inside of buildings is prohibited in certain districts by local authorities or by local inspection departments.

(b) Class A acetylene generators shall not be installed in or upon cars or other railway rolling stock or upon vessels. Properly safeguarded storage systems are permitted.

7. Outside Generator Houses.

(a) Outside generator houses should not be located within five feet of any opening into any building. They must be kept under lock and key and must have natural light during daylight hours.

(b) Generator houses should preferably be constructed of non-combustible material and shall be well ventilated.

(c) The dimensions of specially constructed generator houses should be made no greater than the apparatus requires to allow convenient room for recharging and inspection of parts, and for the storage of the carbide, in accordance with Section 3.

(d) Where artificial heat is necessary to prevent freezing in generator houses, this shall be supplied by a steam, hot water, or other indirect heating system; the heater shall be so located that no flame or fire is in or near the generator enclosure.

8. Foundations.

(a) Where practicable foundations shall be made of non-combustible material. If of wood, they shall be extra heavy, located in a dry place, and open to the circulation of air. A firm platform of ⅞-inch boards on three 2x4-inch stringers is satisfactory for a 25-cubic foot machine and smaller sizes. For larger sizes, wooden foundations must be made of heavy planking on suitable joists or timbers, so arranged that the air can circulate around them and sufficient to afford a firm base for the generator and its contents.

(b) Foundations must be so arranged that the generator will be level and that any unequal strain will not be placed on the generator or its connections.

9. Space About Generators.

Generators must be so placed that the operating mechanism will have room for free and full play and so that it can be adjusted and generators my be charged without artificial light.

10. Accessibility to Unauthorized Persons.

Generator rooms must not be open to unauthorized persons and the generators must not be subject to interference by children or careless persons, and if for this purpose further enclosure is necessary, it must be furnished by means of slatted partitions or other form permitting the free circulation of air.

11. Ventilation of Generator Rooms.

The space about generators should be well ventilated, preferably by some system which affords continuous ventilation, regardless of the period of operation of the generator. All practicable means which will prevent the accumulation of a mixture of gas and air in case of leakage, should be employed.

12. Protection Against Freezing.

Generators must be placed where water will not freeze. No salt or other corrosive chemical is permissible as a protection against freezing.

13. Piping and Escape or Relief Pipes.

Inside Piping.

(a) Connections from generators to service pipes must be made with right and left thread nipples or long thread nipples with lock nuts or approved unions. Unions depending on gaskets to make tight are prohibited.

(b) Piping, as far as possible, must be arranged so that any moisture will drain back to the generator. If low points occur of necessity in any piping, they are to be drained through tees into drip cups permanently closed with screw caps or plugs. No pet cocks shall be used.

(c) The schedule of pipe sizes for piping from generators to burners should conform to that commonly used for illuminating gas, but in no case shall iron pipe be smaller than three-eighths inch size. The following schedule is advocated:

⅜ in. pipe,	26 ft. long,	2 cubic ft. per hour.
½ in. pipe,	30 ft. long,	4 cubic ft. per hour.
¾ in. pipe,	50 ft. long,	13 cubic ft. per hour.
1 in. pipe,	70 ft. long,	27 cubic ft. per hour.
1¼ in. pipe,	100 ft. long,	50 cubic ft. per hour.
1½ in. pipe,	150 ft. long,	65 cubic ft. per hour.
2 in. pipe,	200 ft long,	125 cubic ft. per hour.
2½ in. pipe,	300 ft. long,	190 cubic ft. per hour.
3 in. pipe,	450 ft. long,	335 cubic ft. per hour.

(d) Piping shall be tested with all outlets capped before fixtures are attached with air under a pressure of three pounds per square inch (indicated by a six-inch column of mercury) for a period of thirty minutes, during which time the gauges must show no detectable drop in pressure. After fixtures are attached and piping connected to the generator a second test should be made at one pound per square inch (indicated by a two-inch column of mercury) for a period of thirty minutes, during which time the gauges must show no detectable drop in pressure.

(e) Piping and connections must be installed by persons experienced in the installation of acetylene apparatus.

Outside Piping.

(f) Outside piping shall be standard, full weight, galvanized, wrought-iron or steel pipe with substantial galvanized iron fittings. Exposed threads to be covered with non-corrosive coating.

(g) Outside piping connecting generator with buildings shall be sharply graded to the lowest point outside of buildings and where condensation is not provided for by the piping draining into the generator, a drip shall be provided at such lowest point to take care of condensation. This drip must be so constructed as to permit draining or pumping out the condensation at necessary intervals.

(h) Outside piping must be run as directly as possible, to be carefully protected against injury and laid so that the pipes are pitched to the low point without sags. Proper allowance to be made for expansion and contraction, jarring and vibration.

(i) Pipes leading to the surface of ground must be cased or jacketed where necessary to prevent loosening or breakage.

(j) All outside piping should be laid below the frost line in solid earth and must not be located near nor placed in the same trench with other piping. Propping the pipes on wooden blocks or sticks in the trench is to be avoided. Openings for pipes through outside walls are to be securely cemented and made gas tight.

(k) Gas cock should be provided inside of all buildings where it can be conveniently reached near the point of entrance so as to permit shutting off gas supply from any building.

Escape and Relief Pipes.

(l) Each generator shall be provided with an escape or relief pipe of galvanized iron of the following sizes:

Size of Generator.*	Minimum Size Pipe.
12½ cu. ft. per hour or less	¾ in.
Above 12½, but not over 50 cu. ft. per hr.	1 in.
Above 50, but not over 100 cu. ft. per hr.	1¼ in.
Over 100 cu. ft. per hour	1½ in.

This escape pipe should be made as short and as free from bends as is practicable. If it must be more than 50 feet long or have more than four right angle bends, a pipe of one size larger than that required by this table shall be used.

(m) The escape or relief pipe shall be substantially installed without traps and so that any condensation will drain back to the generator.

(n) The escape or relief pipe shall be carried to a suitable point outside the building, and shall terminate in an approved hood or bend located at least 12 feet above the ground and remote from windows or other openings into buildings and as far as possible from flues or chimneys. The hood or bend shall be so constructed that it cannot be obstructed by rain, snow, ice, insects or birds.

(o) A valve and by-pass connection shall be provided from the service pipe to the blow-off for removing the gas from the holder in case it should be necessary to do so, unless such arrangement is provided as a part of the generator.

14. Water Supply Connection.

Water must not be supplied through a continuous connection leading into the generator. In cases where generators are supplied with water from city water mains or house pipes, no direct pipe connection with the generator is permitted. The supply pipe must terminate some distance above the regularly provided opening for filling so that the water can be observed as it enters the generator.

**See Section 4.*

15. Drain Connection.

Machines of the carbide-feed type must not be fitted with continuous drain connections leading to sewers, but must discharge into suitable open receptacles which may have such connections.

16. Care of Generators.

(a) In the care of generators, always clean and recharge the generating chambers at regular intervals regardless of the number of burners actually used. This work should be done at a regular time, during daylight hours only.

(b) Where generators are not used throughout the entire year, always first remove all carbide and then drain and clean thoroughly at the end of the season during which they are in service.

(c) In order to remove all gas from the machine, it is generally necessary to take out the bell portion and invert it so that the gas can readily escape. This should never be done in the presence of artificial light or fire of any kind. All doors and windows should be open to thoroughly ventilate the room while this is being done.

(d) Whenever repairs are to be made or the generator is to be charged or carbide is to be removed, the water chamber should be full during this operation to avoid the danger of explosive mixtures of air and gas within the water space and also to prevent the dropping of fresh carbide into insufficient water.

17. Re-charging Generators.

(a) In re-charging the generating chambers, clean all residuum carefully from the containers and remove it at once from the building. Never deposit solid residuum or exhausted material in sewer pipes or near any combustible material.

(b) The carbide added each time the generator is recharged should be sufficient to refill the space provided for carbide without ramming the charge. No metal shall be used in distributing the charge.

(c) The proper action and economy of water-feed machines are dependent upon the amount of carbide placed in each of the carbide containers, as otherwise difficulty will be encountered through swelling of the carbide when it comes in contact with water. The instructions of the maker of the generator should be carefully observed.

(d) When re-charging carbide-feed generators, observe the following order of operation strictly: 1, clean out generating chamber; 2, immediately fill the generating chamber with clean water; 3, see that water seals are at proper level; 4, fill hopper with carbide. Never attempt to introduce carbide until after generating chamber is properly filled with water. Be careful not to place in the generators less than one gallon of water for each pound of the carbide capacity and not to bring the water above the point marked on the machine as the proper level.

(e) Whenever any fresh carbide is added to the supply in a carbide-feed generator, this must be done only after the water supply has been completely replenished in accordance with paragraph (d) above. This precaution is necessary to avoid overheating during generation and accumulation of a heavy deposit of residuum in the generating chamber.

18. Manipulation by Daylight Required.

All charging and cleaning of apparatus and execution of repairs shall be done during daylight hours and by natural light only. Never use a lighted match, lamp, candle, lantern or any other flame near the generator.

19. Carbide in Purifiers Forbidden.

No carbide shall be used in filters or purifiers for drying purposes.

CLASS B.
STATIONARY NON-AUTOMATIC APPARATUS.

In addition to compliance with Sections 1, 2, 3, 5, 9, 12, 13, 14, 15, 16, 17 and 18, the following shall apply:

20. Location of Generators.

(a) This type of generator shall be located in a generator house constructed entirely of non-combustible material in accordance with Rule 7.

(b) Where artificial heating is necessary to prevent freezing, this shall be accomplished by a steam or hot water system; the heater shall be located in a separate room with no communicating opening between it and the generating or gas storage rooms.

21. Lighting of Generator Rooms.

Generator or gas-storage rooms, or rooms communicating with these, must not be lighted by any system of illumination involving the use of flames.

22. Ventilation of Generator Rooms.

Generator and gas holder rooms shall be provided with a permanent and effective system of ventilation which will be operative at all times regardless of the conditions of operation of the plant.

23. Accessibility to Unauthorized Persons.

Generator and gas-storage rooms must not be open to unauthorized persons.

24. Foundations.

Foundations shall be substantial, firm and so arranged that the machine will be level and so that no strain will be brought upon the connections.

25. Operation by Daylight Required.

(a) All charging and cleaning of apparatus, generation of gas, and execution of repairs shall be done during daylight hours only.

Never use a lighted match, lamp, candle, lantern, or any other flame near the generator.

(b) Generator houses shall be kept closed and locked except during daylight hours. This will require gas-holders of a capacity sufficient to supply the anticipated lighting load, without the necessity of generation of gas at night.

CLASS C.
SEMI-PORTABLE AUTOMATIC APPARATUS PERMITTED FOR INSIDE INSTALLATION.

In addition to Sections 1, 2, 3, 4, 5, 10, 16 (a) and (b), 17 and 18, the following shall apply:

26. Location of Generators.

(a) Generators shall be placed in well-ventilated locations and upon supports which are adequate to hold them level and to prevent accidental overturning.

(b) Generators shall be so located that they can be re-charged without the aid of artificial light.

(c) Generators shall be placed where water will not freeze.

27. Piping.

(a) Piping shall conform to Section 13 except that seamless brass tubing may be employed if the generator is so designed that in case of a break anywhere in the distributing system the machine will be inoperative.

(b) If conditions for re-charging are such that the machine must be disconnected from the piping system, it may be connected with the piping by metal tubing or pipe having sufficient flexibility through U-bend or coil to allow necessary adjustment for making connection without undue strain on material or joints.

(c) Tubing must be of sufficient internal diameter to insure adequate supply of gas with normal working pressure at the generator.

(d) Tubing must be of sufficient thickness to safely withstand a pressure of 500 pounds per square inch, and in no case lighter than $\frac{1}{8}$ inch outside diameter with $\frac{1}{64}$ inch walls.

(e) Tubing must not be secured in place with staples unless bushed, and must be suitably protected from mechanical injury. It must be protected by sleeves where passing through floors, walls or partitions. It must be supported in ceiling runs at intervals not exceeding six feet.

(f) When installed near electric wiring, rules of National Electrical Code shall be followed. Where tubes cross wires, pipes or other metal, proper protection from mechanical injury shall be provided.

(g) Joints in flexible tubing must be threaded and soldered, brazed or made with a long-contact slip joint union or sleeve with packing of suitable compressible material not affected by acetylene; joints to be capable of withstanding one hundred pounds hydrostatic test.

CLASS D.
STATIONARY AUTOMATIC GENERATORS PERMITTED FOR OUTSIDE INSTALLATION.

In addition to Sections 1, 2, 3, 4, 5, 14, 15, 16, 17 and 18, the following shall apply:

28. Location and Protection Against Freezing

(a) Generators of this class should preferably be located thirty feet from buildings, but never less than ten feet removed and so as not to expose openings into buildings.

(b) Generators must be protected against accumulation of water from surface drainage.

(c) Generators must be protected against freezing. No corrosive chemical is permissible as a protection against freezing.

29. Accessibility to Unauthorized Persons.

Generators shall be kept closed and locked.

30. Re-charging Generators.

See also Section 17.

(a) In the type of generators where the hopper is lifted out for re-charging, care should be taken that the hopper is set in a dry place, not on damp ground or snow, which would cause slacking of the carbide around the feeding mechanism.

(b) Protect against rain or snow in stormy weather.

(c) Use care not to strike sparks with shoe nails and other metal.

31. Piping.

Refer to Section 13 (a) to (k), inclusive, for house piping.

CLASS E.
DISSOLVED ACETYLENE UNDER PRESSURE FOR LIGHTING.

32. Cylinders.

(a) Only approved cylinders which are acceptable for transportation in Interstate Commerce and marked to the effect that they comply with Interstate Commerce Commission regulations (bearing test marks as prescribed in paragraphs 10 and 14 of Interstate Commerce Commission shipping container specification No. 8, effective October 1, 1914) shall be considered suitable for employment in any acetylene lighting installation.

(b) When cylinders are not in use outlet valves shall be kept tightly closed even though cylinders may be considered empty.

(c) All cylinders shall be protected against excessive rise in temperature either from artificial heat or direct sunlight.

(d) When exhausted, cylinders shall be removed from the premises and returned as rapidly as practicable to the manufacturer.

33. Installation.

(a) Cylinders used for stationary installation, including those not in use, shall be kept outside of any building or in well-ventilated compartments of vessels.

(b) Where installed for house lighting, must be protected against mechanical injury or tampering by suitable ventilated box of durable construction arranged to be kept locked.

(c) Cylinders should be connected through

automatic pressure regulators to the permanent house or vessel piping with extra heavy steel tubing or pipe. Connections must be made substantial and so not to strain the house or vessel piping.

(d) Between cylinders and low-pressure piping there shall be installed a pressure gauge to serve as an indicator of pressure in the cylinder or cylinders, provided such gauge is not a permanent part of cylinder, and an approved automatic pressure regulator designed to reduce the high pressure of the cylinders to the low pressure employed in the lighting systems, not to exceed 5 pounds.

(e) On the low-pressure side of the automatic pressure regulator shall be installed an approved pressure relief arranged to release pressure from cylinders in the event of derangement of pressure reducing mechanism which would otherwise allow the accumulation of high pressure from cylinders to enter the low-pressure system.

Such pressure release if of mercury to be of self-restoring type, and to be simple in design and construction.

(f) Discharge from pressure reliefs shall be direct to outside and shall not expose openings into buildings.

34. Piping.

Section 13 shall apply.

CLASS F.

PORTABLE GENERATORS FOR LIGHTING.

(Including Flare Lights).

35.

(a) Apparatus shall be of a type approved for this purpose.

(b) Shall not exceed 150 cubic feet of acetylene in nominal gas capacity.

(c) Shall be used only for out-door illumination, except when special permission is granted by inspection departments having jurisdiction, for temporary use in very large areas, where adequate ventilation is provided.

(d) Shall not be used within 10 feet of combustible material other than the support.

(e) When not in use shall not be placed in any room in which open lights or fires are used. Storage rooms shall be thoroughly ventilated.

PART II.

USE OF ACETYLENE IN WELDING AND CUTTING.

Note: The same general precautions apply to generators used for oxy-acetylene apparatus as for lighting purposes. In general, Sections 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15 and 19 apply. In case a lighting generator of any of the classes described in Part I is used to supply gas for welding any special Section applicable shall be carried out, and an approved flash-back preventer shall be installed in the acetylene line. Standard welding generators have flash-back preventers as part of the construction.

36. Capacity of Generator.

Generators shall be of sufficient capacity to furnish gas up to the maximum rating under working conditions from one charge of carbide for at least one working period of four hours. Charging at other than daylight hours is permitted where generator room is lighted by protected vapor-proof electric lights only. For carbide-feed machines for this service, the rating may properly be one cubic foot of gas per hour per pound of carbide, whereas with water-feed machines the rating should not be more than one-half the above.

37. Location of Generators.

See Sections 6 and 7.

Where generators are installed inside buildings, they must be enclosed in a separate compartment of ample size, constructed of incombustible material, with a self-closing door and the compartment must be so located that during daylight hours it will have natural light and be ventilated to the open air.

38. Piping and Escape or Relief Pipes.

See Section 13, Paragraph (d) shall be modified as follows:

Piping for oxy-acetylene installations shall be thoroughly tested when system is completed. It must not show loss in excess of two inches of mercury within twelve hours when subjected to a pressure equal to a column of fifteen inches of mercury.

39. Care of Generators.

(a) In the care of generators, when the charge of carbide is exhausted or any carbide is added, always thoroughly clean the generating chamber, completly renewing the water supply in accordance with the instruction card furnished by the manufacturer.

(b) When generators are not in use always have the water chamber full unless the generator is out of service for some time, in which case remove the entire carbide charge before removing the water.

(c) Whenever repairs are to be made or the generator is to be charged or carbide is to be removed, the water chamber should be full during such operation to avoid the danger of explosive mixtures of air and gas within water space and also to prevent dropping fresh carbide into insufficient water.

(d) Blow-off or relief valves shall be regularly inspected to be certain that they will function properly and not permit pressure in excess of fifteen pounds per square inch.

40. Dissolved Acetylene Under Pressure for Welding and Cutting.

(a) In systems using dissolved acetylene under pressure, Section 32 shall apply.

(b) Cylinders supplying a system of shop piping shall, whenever practicable, be placed outside of the building.

(c) Cylinders located inside a building may be manifolded or connected to a system of shop piping, or to a single hose line used on large work, only when such total cylinder capacity is less than 2000 cubic feet.

(d) Cylinders inside a building, except those in actual use or attached ready for use, shall be limited to a total capacity of 2000 cubic feet.

(e) For storage in excess of 2000 cubic feet total capacity of cylinders, a separate room, with walls, floor and ceiling equivalent in fire resistance to 3 inches of concrete and with fire doors and fire windows, shall be provided, or cylinders shall be kept outside or in a special building. Special buildings or rooms shall have no open flame for heating or lighting, shall be well ventilated and shall have no other occupancy, except that they may be used for the storage of calcium carbide.

(f) An approved regulator shall be used between any cylinder or manifold containing acetylene under pressure in excess of fifteen pounds per square inch, and the piping or hose supplying appliances. Regulators shall be so adjusted that the gas pressure leading to the point of consumption will never exceed fifteen pounds per square inch.

(g) An approved service acetylene regulator shall be used at every point in shop piping system where acetylene is drawn off to supply a blow-pipe or other gas-burning device. Service regulators must be similarly employed in the oxygen supply system.

(h) Manifolds shall be constructed of double extra heavy piping not exceeding 1¼ inch pipe size, and shall have extra heavy connections (not over ½ inch pipe size) from each cylinder, so arranged as to give the necessary flexibility with the minimum amount of pipe. The manifold pipes and connections between the manifold and the cylinder should be constructed so as to be

capable of standing a test pressure of 1000 lbs. per square inch. Suitable steel tubes, block tin, or an approved composition pipe should be employed for the connections between the cylinders and the manifold pipe. Copper must not be used.

(i) Approved flash arresters shall be employed at the outlet of each cylinder when connected to a manifold and at each inlet into the manifold. Each inlet into the manifold shall be provided with a suitable shut-off valve. A flash arrester of the low-pressure type and approved design should be installed between the master regulator and the shop piping.

(j) Adapters used to connect fittings to cylinders containing gases under pressure shall be of substantial design and construction and shall be of sufficient strength to afford ample factor of safety in the service intended.

(k) No acetylene, or oxygen cylinder while charged shall be transported or lifted by crane or derrick inside a building, and cylinders shall never be handled with electromagnets.

(NOTE—The transportation through the air of any cylinder containing a compressed gas introduces the probability of rupture of the cylinder in case it is dropped, with the consequent injury of workmen and property. It is recognized that under many circumstances, particularly in wrecking work and in conjunction with interior work in ships and in buildings of considerable height, it will be necessary to lift and transport cylinders, in which case cradles and not slings shall be used and extreme care shall be exercised.)

41. General.

Oxygen generators, compressors or cylinders, or the chemicals from which oxygen is derived, shall not be located in the same room with an acetylene generator.

42. All blow pipes, torches, regulators, hose and other appliances shall be of an approved design and shall be regularly inspected and kept in good condition. Repairs to be made only by persons thoroughly familiar with such apparatus.

43. No appliance shall be installed in any line which causes or allows the mixture of air or other oxygen carrier with acetylene, except directly at the blow-pipe or burner.

44. All parts of generators of acetylene or oxygen shall be carefully inspected at frequent intervals to detect cracks or corrosion.

45. Hose.

(a) The hose necessary to connect blow-pipes to gas outlets should be of a good quality of rubber, having a sufficient number of plies of fabric to withstand the service for which it is employed.

(NOTE: While in some classes of light work it is desirable to have a light and flexible hose, this hose should be capable of withstanding a hydrostatic pressure of 200 pounds per square inch held for 5 minutes. For heavier service and for hose carrying gases under pressure higher than 15 lbs. per square inch a hose capable of withstanding a test pressure of 400 pounds per square inch should be used.)

(b) In heavy service, as in foundries and machine shops, hose shall be protected against abrasion and kinking by an outer covering of tough, durable material which will not add excessively to the weight or seriously reduce the flexibility of the hose.

(c) Hose connections must be made through substantial fittings and clamped to these connections in such a manner as to withstand without leakage a pressure twice as great as may be obtained through regulating valves provided on the systems.

46. Valves to be Shut Off.

During operation, valves on permanent piping or at generator or pressure tank to be used to shut off flow where operation is to be discontinued for a considerable period of time. In all cases on the shutting down of operation for the day, valves on the pressure tank or the generator shall be closed, and also valves and regulators on the oxyger supply.

47. Portable Generators for Welding.

(a) Apparatus shall be of a type specifically approved for this purpose.

(b) Shall not be used within 10 feet of combustible material other than the floor.

(c) Shall not be used in rooms of total volume less than 100 times the nominal aggregate gas-generating capacity of all such generators in the room.

(d) Shall be cleaned and recharged and air mixture blown off outside buildings. Special exceptions may be granted by inspection departments having jurisdiction in large-area, well-ventilated one story buildings.

(e) Shall not when charged be moved by a crane or derrick.

(f) When not in use shall not be placed in any room in which open lights or fires are used. Storage rooms shall be thoroughly ventilated.

HEAT TREATMENT OF STEEL*

IT is the purpose of this article to present, for the purpose of those unacquainted with the subject, only a brief general explanation of the principles involved in the scientific heat treatment of steels as a means to improve their physical properties. The subject is too broad and too many ramifications are involved to attempt here to present actual data for to do so with any degree of completeness would require volumes in itself. For a better general understanding of the art the reader is referred to works of J. M. Camp and C. B. Frances[1], and to those desiring to make a more exhaustive study to the works of Albert Souveur[2], H. M. Howe[3], and D. K. Bullens[4], Much of the information contained herein is derived from these sources.

Nearly all steel made is heated during some process of its manufacture, either for the purpose of rendering it plastic in order that it may be worked into some desired shape or form or for annealing. Many steels are necessarily heated several times and some, for the purpose of improving their physical properties are subjected to several heat treatments; these treatments vary in respect to the method of applying heat, the amount of heat applied and the nature of the cooling treatment given after heating, all for the purpose of attaining some certain desired property or properties in the steel.

It has been known for many years that the physical properties of steel were subject to pronounced changes through heat treatment, it was until only of recent times however that the subject received much attention from scientists and was limited to the preparation of tool steels and in a few instances for other special purposes, with the advent of the automobile, the aeroplane and other modern machines and machinery came the demand for steels having special properties such as hardness, ductility, great strength or combinations of certain of these properties within specific limits and all with the requirement of minimum weight. This brought about the development of the art to embrace the highly scientific processes now generally in use.

For initially working ordinary steels they are brought to comparatively high temperatures ranging from say 1500° F. to 2300° F. depending on the nature of the steel and the purpose for which it is intended. When cooled, whether rapidly or slowly from these high temperatures the structure of the steel will be coarse grained, that is, the crystals forming the structure will be comparatively large or coarse. The grain coarseness of untreated steels is dependent on the temperature to which it has been heated, its chemical composition, in particular to the amount of carbon present in its content and to an extent the amount and nature of the work put on it when rolling, forging, etc.

Practically all alloy steels must be heat treated in order to obtain the best results from it, and few steels in their natural state will give their best service without co-relating both the chemical composition and the heat treatment required for that particular composition in relation to the specific purpose to which the steel is put to or the particular property in the steel that it is desired to develop. The rapidity with which heated steel is cooled also affects, to a degree the crystal formations and therefore its physical properties.

Heat treatment therefore consists in heating and cooling steel under exact conditions co-relating with its chemical composition to produce the desired physical properties which best suit it for the purpose it is required to serve.

The nature of the crystalline structure of steel has a very marked influence upon its strength and ductility, this can be changed by heat treatment, not only with reference to the size of the crystals but also their shape or geometric form. The process of solidification, that is the tendency for fluid or molten steel to assume solid form due to cooling, is accompanied by crystallization; during this period primary crystals are formed, this consists of the development of microscopic tree-like bodies called dendrites, these in turn are composed of small octahedra or eight sided crystals. In reheating the steel, after solidification is complete, a granular crystal transformation begins. The size of these grains vary with the reheating temperature, the amount of work put on the steel in rolling or forging, etc., and to an extent with the carbon content of the steel. Structural and other changes take place at temperatures known as the thermal critical points or critical ranges, the points in the heating or cooling where spontaneous evolution or absorption of heat takes place; this is due to the rearrangement of the constituents forming the structure which takes place at this period. The chemical composition of the steel and the addition of alloys while the steel is in the process of manufacture, have marked effect on the critical temperature ranges.

In pure steel which has been allowed to cool slowly from a high temperature, three distinct primary constituents are found, ferrite, pearlite and cementite[1]; these vary in different steels in proportion to the variations of their carbon content.

Ferrite is the term applied to pure iron[2], (iron without carbon or other impurities) it is very soft, ductile and relatively weak, and has no hardening property.

Cementite: Iron plus carbon are the essential elements of steel, that is the two elements that must be present in all steels of any nature. Of these two, carbon is the controlling element or that which determines the hardness and strength of the steel; these are in proportion to the amount of carbon present. The ductility on the other hand decreases as the carbon is increased. In steel slowly cooled from high temperature the carbon is found combined in definite relation with iron in the form of iron carbide, this is known as **cementite.** If there is iron present in excess of the exact amount that will combine with the carbon it will remain in its pure state as ferrite. Not much is known of the properties of cementite except that it is hard and brittle, lending these properties to the steel in proportion to the extent it is present. It is the hardest component of steel.

Pearlite: Cementite and ferrite have the

[(1*See "The making, shaping and treating of Steel," by J. M. Camp and C. B. Francis, published by the Carnegie Steel Co., Pittsburgh, Pa.*) (2*See the "Metallography and Heat Treatment of Iron and Steel," published by Sauveur and Boylston, Metallurgical Engineers, Cambridge, Mass.*) (3*See "Iron, Steel and Other Alloys," and "The Metallography of Iron and Steel." Both published by McGraw-Hill Book Company, Inc., 239 West 39th Street, New York.*) (4*See "Steel and Its Heat Treatment," published by John Wiley & Sons, Inc., New York, City.*]

**Written for The Welding Encyclopedia by W. H. Bailey.*

property of forming in a conglomerate known as Pearlite. This constituent consists of interstratified layers or bands of ferrite and cementite. Under different conditions or rates of cooling and dependent on the relative amounts of ferrite and cementite present, pearlite exists in other formations, of which four have been recognized making in all at least five modifications. Pearlite has high tensile strength and low ductility.

To summarize, each constituent, ferrite, cementite and pearlite has the power to impart its own peculiar property to the steel in proportion to the extent it is present in the metal.

Annealing[3]

In general the purpose of annealing is for one of the following reasons: 1st to soften the steel in order that it may be more easily machined or to meet certain physical requirements. 2nd, to relieve internal stresses due to uneven cooling or in working the steel into form. 3rd, to refine the grain structure to improve the strength, ductility and elasticity of the steel. This treatment is generally given to cold rolled or cold drawn steel which loses its ductility during these processes and must be restored to permit further working or to suit the final purpose for which the product is to serve; to hot forged products to improve their grain structure and to steel castings to remove internal strains and to improve their grain structures and related properties..

In ordinary annealing the steel is placed in a furnace and slowly brought up to a temperature slightly exceeding the upper range of critical temperature or where the crystal formation is completely rearranged and then slowly cooled. The time element is of great importance sufficient time must be allowed, particularly with large pieces, to uniformly heat it throughout in order that all parts are treated alike and have a uniform structure.

The cooling of the heated steel is also of prime importance, the quickest possible cooling will produce the maximum hardness, and the slowest cooling the maximum degree of softness possible with relation to the carbon content of the steel. Inasmuch as the variation in the time allowed for cooling affects so pronouncedly this property of steel the process is by no means simple and for exact effects definite knowledge is required of the composition of the steel and the specific nature of its response to heat treatment with respect to its structural arrangement. In steels having less than .90% carbon content a very slow cooling from the annealing temperature allows the excess ferrite to separate and surround the hard and brittle pearlite grains with soft and ductile envelopes. A relative rapid cooling will produce fine grains with the excess ferrite mixed with the pearlite in patches. The formation of pearlite by slow cooling is gradual through the ranges of critical temperature and takes place by stages from austenite to martensite to troostite to sorbite to pearlite, each having its own peculiar formation and property and each controlled by the rate of cooling. The amount of carbon present is also a factor to be considered with reference to cooling. Low carbon steels may be cooled more rapidly than those of higher carbon, also the size of the piece should be taken into consideration, heavy bodies of steel may be cooled relatively quicker or by a quicker process than smaller bodies.

There are three general methods of cooling.[4] 1st—Air cooling or normalizing; the piece is removed from the furnace while hot and allowed to cool in the air, the size of the piece and the carbon content are factors to be considered when air cooling and definite suggestions have been made by the American Society for Testing Materials in this respect. 2nd—Furnace cooling or annealing; here the piece is allowed to cool gradually and slowly within the furnace, usually after the latter has been sealed up to retard cooling and guard against draughts. This method tends to give maximum softness and ductility. 3rd—Insulated cooling or modified annealing; the piece is removed from the furnace and covered with some insulating material such as sand or ashes or it may be placed in an air tight pit and allowed to cool. In some cases after the piece has been cooled by one of the above processes to where it has become black, it is immersed in water—this for the purpose for which it is intended, has no harmful effect, and hastens the completion of the operation.

If the object being annealed is exposed to free oxygen, oxidation will take place and the exposed surface will be covered by a film of scale, where it is desired to keep the surface bright, or to protect it from decarbonization, it is the usual practice to place the steel in a metal box called an annealing box, some refractory such as ground mica or sand being included or in some instances ground bone or charcoal mixed with ashes or some other substance that will oxidize at lower temperature than the steel. Also non-oxidizing furnaces are sometimes used where the steel is surrounded by non-oxidizing gases.

Hardening and Quenching

The process of hardening steel involves heating to a proper temperature corelated to its chemical constituents and quickly cooling or quenching in some suitable liquid. In properly hardened steel the original nature of the structure, that is the arrangement, size and formation of the crystals have been completely changed from that which existed before the treatment. Usually high carbon steels or alloy steels are subjected to this treatment. The steel should be heated slowly and evenly to just above its range of critical temperature. In order to obtain the desired temperature the heating is sometimes done in a bath of lead or of the chlorides of sodium, calcium, potassium or barium. For hardening the cooling must be very rapid. Under annealing it was explained how pearlite was formed during slow cooling through a series of transitions, austenite to martensite to troostite to sorbite to pearlite. If cooling is accomplished with proper rapidity through the range of critical temperature this transition may be controlled, to produce martensite, troostite, sorbite and pearlite. Neither sorbite or pearlite are true constituents of hardened steel, some sorbite however may be found in either of these two classes of steel due to a tendency to overlap.

The cooling treatment for hardened steels is accomplished through various mediums dependent on its chemical composition and size and the particular property it is desired to attain, the most rapid method in use is to spray with water under pressure, the next rapid is to immerse in brine, the next to immerse in water or in mercury, then immersion in oils; these latter have quite pronounced range of effectiveness, depending on their viscosity, volatility, specific heat, etc. For some purposes it has been found advantageous to have combination mediums such as oil and water.

Tempering or Drawing[5]

Tempering or drawing consists in reheating hardened steel to some temperature below the critical range and is intended to regulate its hardness and brittleness, to toughen it or to relieve it of stresses. Care must be exercised in tempering not to too closely approach the critical range of temperature. Inasmuch as proper tempering does not affect the primary structure of the steel it is immaterial what method of cooling or quenching is used. The original method of estimating tempering temperatures was by the use of the color chart. If a piece of

[1] *See "Ferrite," "Cementite," "Pearlite."*
[2] *See "Testing Weld."*
[3] *See "Annealing."*
[4] *This refers to the manufacture of commercial steel. (See "Preheating.")*

hard steel is polished and then heated slowly in contact with air, a film of oxide will form on the polished surface, this film will undergo a series of color changes beginning with pale yellow and continuing through the yellows, browns, purples, blues, and finally the reds to dark red. The objection to the color method is that it has its decided limitations through the extent to which the human element is involved and to the fact that the pronouncement of the colors are affected by the amount of light present. For instance, at the same temperature a temper color may have a different appearance in the sunlight than it has when examined in a darkened room. More scientific methods have now come into use such as sand baths, liquid baths and the use of pyrometers to control the temperatures of these baths.

In addition to hardness other physical properties of steel are affected by tempering, as hardness is decreased, the tensile strength and elastic limit are also decreased proportionately while the ductility will be increased. The presence of sorbite in steel may be considered as denoting the connecting link or to denote the zone of demarkation between annealed steels and hardened steels, its presence being usually undesirable in either, and as pearlite is the predominating constituent of the lower carbon or annealed steels so martensite is the predominating constituent of the high carbon or hardened steels. The presence of troostite is usually a result of tempering or a secondary heat treatment where the amount of heat applied is controlled within definite ranges below the critical range of temperature and a subsequent quenching of the piece in oil or some other medium. If the temperature is allowed to exceed within limitations that necessary to produce troosite a sorbitic structure will result, tempering here will toughen the steel pronouncedly but with the accompanied loss of much of the hardness.

[5]*See "Temperature Color Chart."*

Toughening of Steel

This term is applicable to treatments given certain medium carbon steels for specific purpose, usually where the metal is subject to fatigue such as railway axles, working parts of reciprocating machinery subject to heavy and fatiguing loads and so on. The treatment consists in giving the already treated steel a secondary or drawing back treatment to an extent that the hardening effect of the primary treatment is practically nullified. The benefit of this treatment lies in the fact that the strength and the ductility of the steel may be developed to the maximum permitted by its chemical composition; it follows therefore that the treatment is valuable where it is desirable to obtain a maximum ductility.

Case Hardening[6]

If iron or steel be placed in a vessel in contact with carbonaceous material and heat applied approaching or exceeding the critical range, the metal will absorb carbon, the amount absorbed being dependent on the time in contact at high temperature, the temperature prevailing, the composition of the metal and the quality and nature of the carbonaceous medium used. The effect of this treatment is to greatly increase the carbon content at and near the surface of the object, leaving an unaffected, ductile core.

This process is used to a considerable extent in the manufacture of gears, tools and parts of machinery where a hard surface is required while the center must be left soft enough for machining. To obtain the best results from case hardening the initial process should be succeeded by heat treatment. This process is usually of a special nature having as objectives the highest development for both the high carbon case hardened surface and the low carbon interior or untreated surfaces, as the case may be.

[6]*See "Case Hardening."*

Training Operators

Training Operators

THE course outlined here for the training of men for oxy-acetylene welding is based upon the report prepared by the Committee on the Training of Welding Operators of the American Bureau of Welding through the joint co-operation of the American Welding Society, the Federal Board of Vocational Education, and the National Research Council. It represents the best knowledge available, not only from the welding standpoint, but also from the experience of the Federal Board of Vocational Education in drawing up courses for vocational training. All welding schools are urged to give it the most careful consideration, and use it as a guide in laying out courses for training operators.

The topics included in the lesson courses and the practical work included in the exercises will be followed systematically, furnishing the student with sufficient knowledge and skill to enable him to make an agreeable showing in the welding shop. Particular attention is called to the fact that the work of the committee mentioned above has been supplemented by including with each lesson a guide of reference reading which can be made in **The Welding Encyclopedia.** These reference readings can be used by the student to enable him to get complete information on the subject of the lesson, and by the instructor as a supply of information for lectures and lesson sheets. The type jobs given in the exercises are intended to suggest rather than specify the work to be done. Sections can be made from these jobs or similar jobs substituted, according to the facilities available or the preference of the instructor.

The course outlined for training electric arc welders is similar in structure to the oxy-acetylene welding course and is based upon the instruction given in the best arc welding schools in America. Emphasis has been placed where the necessity for it has been indicated by supervisors of extensive arc welding departments, so that it represents in the main the requirements of the industry, at the same time following a perfectly logical development.

In connection with the training of operators, it is recommended that advantage be taken of the material presented in the section on "Examination of Operators."

Training Course for Oxy-Acetylene Welders

LESSON I

SUBJECT—**Oxy-Acetylene Welding and Oxy-Acetylene Torches.**

Oxy-acetylene welding—Types of torches—Safe construction—Principle of the Cutting Torch.

REFERENCE READING—**Encyclopedia Section:** Torch Classification; Cutting; **Oxy-Acetylene Welding Chapter:** Introduction; Use and Misuse of Equipment (Torches). **Rules and Regulations:** Underwriters' Laboratories Specifications, No. 29.

LESSON II

SUBJECT—**Regulators and Gauges.**

Construction and principle of operation of pressure regulators—Oxygen and acetylene regulators—Importance of tight seats—Safe construction — Maintenance — Abuses to be avoided—Construction and principle of operation of gauges—Care of gauges.

REFERENCE READING—**Encyclopedia Section:** Regulators; Bourdon Tube. **Oxy-Acetylene Welding Chapter:** Use and Misuse of equipment (Regulators). **Rules and Regulations:** Underwriters' Laboratories Specifications, No. 28.

LESSON III

SUBJECT—**Torch and Regulator Troubles.**

Leaky handle valves—Leaky tips—Plugged gas passages—Why valves and tips should not be ground—Creeping regulators—Replacing seats—Checking gauges—Buckled diaphragms—Leaks in new regulators.

REFERENCE READING—**Encyclopedia Section:** Bourdon Tube; Creeping; Torch Specification. **Oxy-Acetylene Welding Chapter:** Use and Misuse of Equipment (Regulators and Torches).

LESSON IV

SUBJECT—**Construction and Handling of Gas Cylinders.**

Construction of oxy-acetylene tanks and oxygen tanks—Interstate Commerce Commission requirements — Charging pressures — Safety plugs—Care and handling—Dangers when exposed to extreme temperatures—Importance of opening valves slowly—Difference between oxygen and acetylene tanks—Locating leaks of acetylene by odor—Danger of using flames to locate leaks.

REFERENCE READING—**Encyclopedia Section:** Acetylene; Acetone; Cylinders; Oxygen. **Oxy-Acetylene Welding Chapter:** Use and Misuse of Equipment (Oxygen and Acetylene Cylinders). **Rules and Regulations:** Interstate Commerce Commission's Specifications for Shipping Containers—National Board of Fire Underwriters' Regulations, No. 40.

LESSON V

SUBJECT—**Character of Gases.**

Acetylene, the most important gas — Methods of producing acetylene—Physical and chemical characteristics of acetylene—Reasons for combining acetylene with acetone—Methods of producing oxygen—Use of oxygen in welding and cutting—Blau Gas—Butane—Calorene — Hydrogen — Pinch gas—Street gas—Thermalene.

REFERENCE READING—**Encyclopedia Section:** Acetone; Acetylene; Blau Gas; Butane; Calorene; Hydrogen; Oxygen; Pinch Gas; Street Gas; Thermalene.

LESSON VI

SUBJECT—**Acetylene Generators.**

Construction and operation of acetylene generators—Rules and Regulations of the National Board of Underwriters—Storage of carbide—Safe methods of charging.

REFERENCE READING—**Encyclopedia Section:** Acetylene; Generators; Pipe Lines. **Oxy-Acetylene Welding Chapter:** Use and Misuse of equipment (Acetylene Generators). Gas storage and Distribution. **Rules and Regulations:** Underwriters' Laboratories — Standards of Construction for Stationary Acetylene Generators—Specifications of the National Board of Fire Underwriters, No. 27 —Rules and Regulations for the Installation and Operation of Acetylene Generators.

LESSON VII

SUBJECT—**Preparation for Welding.**

Beveling—Different methods of welding—Designs for welding joints—Use of asbestos and carbon paste—Jigs—V blocks.

REFERENCE READING—**Encyclopedia Section:** Asbestos; Backward Welding (Pre-

paration of the Metal); Beveling; Butt Welding; Carbon; Caulking Weld; Composite Weld; Concave Weld; Design of Weld; Fillet Weld; Flush Weld; Jigs; Lap Welding; Flush Welding; Reinforced Weld; Strap Weld; Strength Weld; Tack Weld; Tee Weld. **Oxy-Acetylene Welding Chapter:** Introduction; **Charts and Tables:** Instruction Chart; Preparation of Parts to be Welded.

LESSON VIII

SUBJECT—**Setting up Apparatus.**

REFERENCE READING—**Encyclopedia Section:** Carbonizing Flame; Oxidizing Flame; Neutral Flame. **Oxy-Acetylene Welding Chapter:** Introduction.

LESSON IX

SUBJECT—**Welding Rods.**

The selection of rods for different metals—Characteristics of good welding rods.

REFERENCE READING—**Encyclopedia Section:** Welding Rods and Wire; **Oxy-Acetylene Welding Chapter:** Selection of Welding Rods.

LESSON X

SUBJECT—**Preheating and Annealing.**

Reasons for preheating—Contraction—Expansion—Methods and apparatus for preheating—Annealing.

REFERENCE READING—**Encyclopedia Section:** Annealing; Asbestos; Contraction; Expansion; Preheating; Sheet Metal Welding; Tip Welding. **Oxy-Acetylene Welding Chapter:** Introduction. **Boiler Welding Chapter:** Expansion and Contraction. **Pipe Welding Chapter:** Pipe Welding Procedure. **Tank Welding Chapter:** Gas Welded Tanks; Rigid and Non-Rigid Systems of Welding; Controlling Contraction.

LESSON XI

SUBJECT—**Torch Manipulation.**

Different methods of handling the flame—Protecting the puddle—Adhesion—Cohesion—Penetration.

REFERENCE READING—**Encyclopedia Section:** Adhesion; Cohesion; Backward Welding; Penetration. **Oxy-Acetylene Welding Chapter:** Torch Manipulation.

LESSON XII

SUBJECT—**Welding Cast Iron.**

Different grades of cast iron—Preparing the weld—Selecting the filler rod—Selecting the tip—Regulating the flame—Welding cast iron—Cooling.

REFERENCE READING—**Encyclopedia Section:** Cast Iron (Hard Spots). **Oxy-Acetylene Welding Chapter:** Welding Cast Iron.

LESSON XIII

SUBJECT—**Welding Steel.**

Structure of steel—Influence of the welding flame—Methods of welding—Methods of etching steel welds to determine quality.

REFERENCE READING—**Encyclopedia Section:** Steel, Structure and Restoration of; High Speed Steel; Chrome Steel. **Oxy-Acetylene Welding Chapter:** Welding Steel. **Chapter on Heat Treatment of Steel.**

LESSON XIV

SUBJECT—**Welding Aluminum.**

Properties of aluminum—Different methods of welding aluminum.

REFERENCE READING—**Encyclopedia Section:** Aluminum Utensils; Crank Cases; Sheet Aluminum. **Oxy-Acetylene Welding Chapter:** Welding Aluminum.

LESSON XV

SUBJECT—**Welding of Copper, Brass and Bronze.**

Properties of copper, brass and bronze—Selection of welding rods—Use of flux—Hammering and annealing—Execution of the weld.

REFERENCE READING—**Oxy-Acetylene Welding Chapter:** Welding of Copper, Brass and Bronze.

LESSON XVI

SUBJECT—**Brazing.**

Preparation—The use of flux—Precautions to be observed—Applications.

REFERENCE READING—**Encyclopedia Section:** Brazing; Brazing, Electric; Brazing, Production Work; Malleable Iron; Locomotive Cylinders.

LESSON XVII

SUBJECT—**Welding Monel Metal.**

Properties of monel metal—Selecting the tip—When to use flux—The execution of welds—Welding monel metal rods, sheets and castings.

REFERENCE READING—**Encyclopedia Section:** Monel Metal. **Tank Welding Chapter:** Welding Monel Metal Tanks.

LESSON XVIII

SUBJECT—**Lead Welding.**

Reason for using less heat—Preparation of the surfaces—Welding procedure—Vertical welding—Storage battery work.

REFERENCE READING—**Encyclopedia Section:** Lead Burning.

LESSON XIX

SUBJECT—**Soldering.**

Soft solders and hard solders—How to mix—Selections of flux—Silver soldering—Soldering aluminum—Electric soldering.

REFERENCE READING—**Encyclopedia Section:** Soldering.

LESSON XX

SUBJECT—**Cutting.**

The oxy-acetylene cutting process—Principle of the cutting torch—How to secure economy—Inclining the torch when cutting—Oxygen consumption — Cutting tanks and cylinders—Cutting cast iron—Cost of steel cutting—Cutting under water—Mechanically operated cutting torch.

REFERENCE READING—**Encyclopedia Section:** Cutting.

LESSON XXI

SUBJECT—**Automobile Welding.**

Variety of automobile work—Use of bronze—Carbon burning—Welding motor heads—Radiator repairs—Chassis welding—Automobile cylinders.

REFERENCE READING—**Encyclopedia Section:** Automobile Cylinders; Automobile Welding; Carbon Burning; Crank Cases; Motor Heads; Radiator Repairs; Crank Shafts; Fender Welding; Asbestos; **Carbon.**

LESSON XXII

SUBJECT—**Boiler Welding.**

Advantage of welding over riveting—Care of tools—Safety precautions—Selection of welding rods—Preparing the work—Expansion and contraction.

REFERENCE READING—**Boiler Welding Chapter. Rules and Regulations:** A. S. M. E. Code; Department of Commerce Steel Boat Inspection; Service Rules and Regulations; Lloyd's Register of Shipping; Regulations and Tests; State Rules.

LESSON XXIII

SUBJECT—**Pipe Welding.**

Advantages of welded pipe joints—Pipe welding procedure — Pressure pipes — Gas transmission—Welded pipe in the oil fields—Savings occasioned by welding.

REFERENCE READING—**Encyclopedia Section:** Pipe Welding; Refrigerating Machinery. **Pipe Welding Chapter.**

LESSON XXIV

SUBJECT—**Tank Welding.**

Storage tanks—Pressure tanks—Preparing for welding—Heading large and small tanks—Rigid and non-rigid systems of welding—Controlling contraction — Welding pipe to tanks—Designs for tank joints—Nomenclature of tank joints.

REFERENCE READING — **Chapter on Tank Welding. Charts and Tables;** Preparation of Parts to be Welded.

EXERCISE I

Setting up apparatus—Producing and adjusting of torch flame previous to using torch.

OBJECTIVE—To properly adjust torch flame for welding—To realize the importance of care in using the flame and equipment—To obtain some knowledge of the nature of the gases used—To be able to assemble and set up apparatus—To be able to change regulator from one cylinder to another.

AUXILIARY INFORMATION—**Stock:** No recognition of stock is needed at this beginning period—One should be able, however, to recognize the gases used (1) by the appear-

ance of the containers, (2) by their odor, (3) by their burning characteristics. **Trade Terms:** Materials, such as acetylene, oxygen —Tools and equipment, such as torch, tips, regulators, hose, tanks, and containers. **Safety First:** Use of goggles to protect the eyes and gloves to protect the hands—Caution so as not to burn others or oneself—And care in directing the flame so as not to injure the equipment, such as hose—Student should be cautioned to extinguish the flame by turning off the gas when not in use.

MISCELLANEOUS—Creation of the most intense flame by the burning of acetylene by the aid of pure oxygen—Acetylene is produced by dropping carbide into pure water—Oxygen is one-fifth of the volume of air and is produced commercially by (1) liquid air, (2) electrolytic process.

EXERCISE II

Using torch on piece of cast iron to melt the surface.

OBJECTIVE—To melt the surface of cast iron, successfully overcoming all incidental difficulties.

AUXILIARY INFORMATION—**Stock:** Recognition of cast iron, (1) by the appearance of the surface, (2) by the fracture, (3) by the action of the torch flame—And recognition of its working properties, such as (1) easy melting, (2) fluidity. **Care of Equipment:** Avoidance of flashback and knowledge of the proper procedure after a flashback has occurred. **Safety First:** Knowledge of the danger resulting from flashbacks—Necessity of keeping torch flame inside the field of vision so as not to injure others—Loose tools and materials. **Miscellaneous:** Oxy-acetylene flame is approximately two and one-half times as hot as the melting point of cast iron —The conductivity of two metals such as cast iron and copper vary considerably—Formation of oxide and elimination by flux—Cast iron should be cooled slowly to prevent "hard spots."

EXERCISE III

Adding metal to a flat surface.

OBJECTIVE—To be able to successfully melt the filler rod into the plate.

AUXILIARY INFORMATION—**Stock:** Welding rod—Flux. **Miscellaneous:** All metals should be melted to make a weld.

EXERCISE IV

Building up "bosses" on flat surfaces.

OBJECTIVE—To be able to build a "boss" an inch in diameter and an inch in height—To possess control over the melted metal in flat welding—And to use the proper amount of flux.

AUXILIARY INFORMATION—**Stock:** The working properties of metal with or without the use of flux.

EXERCISE V

Welding two prepared flat pieces of cast iron not over ⅜-inch thick and 2 inches in length, single V.

OBJECTIVE—To properly weld two prepared, flat pieces of metal together, using the proper amount of filler.

EXERCISE VI

Reducing an irregular surface to a definite level.

OBJECTIVE—To produce a level surface, free from blowholes and hard spots—To control the metal and prevent it from flowing over unguarded edges—Student should test finished surfaces for imperfections.

AUXILIARY INFORMATION—**Stock:** Working properties of stock as affected by foreign elements, such as dyes, oils, grease, etc. **Miscellaneous:** Metal in molten state seeks a level—In welds, the molten metal can be maintained out of level by proper handling of the torch.

EXERCISE VII

Locomotive Bell Crank—Cap for Water Meter—Exhaust Manifold Lug—Tail Stock Clamp Lever—Crank in Driving Box Shoe—Stove Door—Furnace Shaker—Piano Ring—Printer's Chase—Furnace Door—Piano Pedal.

OBJECTIVE—To be able to produce a weld in a simple piece of cast iron in which alignment and finish are of minor importance.

AUXILIARY INFORMATION—(a) Preparation for welding including "V"-ing and lining up the work—(b) Treatment of pieces after welding including slow cooling to avoid hard spots—(c) Finishing.

EXERCISE VIII

Lugs on Grease Collar—Flange on C. I. Manifold for Gasoline Engine—C. I. Water Heater—Water Manifold (C. I.) for Gas Engines, (Ford)—Lug on Pump Cylinder—Tooth on Gear Wheel—Cylinder Head on Single Cylinder Gas Engine—C. I. Vise Jaw —Lug on 4-Cylinder Block—Broken C. I. Scale Lever.

OBJECTIVE—To do a little more difficult work than in previous checking level.

AUXILIARY INFORMATION — (a) Increased accuracy is required in preparation, welding and finishing—(b) The use of straight edge when necessary.

EXERCISE IX

C. I. Water Back—Crack in Grease Collar —Lugs on Driver Boxes (Cast Iron)—Cable Drum, where worn out by cable—6 inch Pump Cylinder cracked from end to end—Water Jacket for Gas Engine—Cracked Jacket on Automobile Cylinder (1 to 6 Cylinders)—Building-up Valve Seats—Cracks in Auto Cylinder Exhaust Parts—Scores in Cylinder.

OBJECTIVE—To be able to weld jobs involving elementary principles of pre-heating.

AUXILIARY INFORMATION—(a) Necessity of still greater accuracy and care in preparation and welding—(b) Avoidance of distortion from preheating or welding—(c) Avoidance of cracking after welding. **Miscellaneous:** (a) Expansion and contraction of metals due to change in temperature—(b) The use of steel scale, trams, and dividers as precision measuring instruments.

EXERCISE X

Woodworking Machinery Side Frames—Locomotive Cylinder Flange—High Pressure Steam Manifold—Corners of Water End of Duplex Pump—Printing Press Frame—Cylinder Head (piece broken out of edge)—Trailer Box (weld lugs for holding grease collar)—Rack for Steam Shovel (broken in halves)—Flange on Sheave Wheel (piece chipped out) —Punch Press Frame—Sheave Base—Cylinder Valve Chamber—Tooth in Rack for Steam Shovel—Valve Chamber for Pump—Pump Cylinder (cracked around flange)—Gas Engine Crank Case—C. I. Belt Pulley Spokes and Rims—C. I. Pipe 4 inches and up—Fire Hydrants or Street Light Posts—C. I. Radiator Sections—Centrifugal Fan Housing (two man job)—Hoisting Engine Drum (two man job)—Steam Chest on Wrecker Engine (cracked through stud holes in corners).

OBJECTIVE—To be able to do more difficult welding jobs involving further application of the principles of pre-heating and the use of a larger torch tip.—To be able to co-ordinate work with more than one welder working on the same job at the same time, as well as when working in relays.

AUXILIARY INFORMATION—(a) Instruction in the use of a drill press, air drill, air hammer, sledge hammer and track chisel as they are used in "V"-ing—(b) instruction on the responsibility of the welder involving the safety precautions which should be observed in order to prevent injury to himself or others—(c) Necessity of good work to avoid failure in service after welding which might endanger property or life—(d) Development of ingenuity on the part of the welder. **Miscellaneous:** Further application of measuring tools as mentioned above.

EXERCISE XI

Flange on Sprocket Case for Loco Stoker—Cast Iron Boiler Front—Large Gear Wheel. (broken in several pieces)—Planer Bed—C. I. Crank Case (badly broken)—Patch on Radius Pipe for Loco Stoker—Trailer Box (build up where worn)—Fly Wheel (broken spokes or cracked hub or piece broken out of hub) wheel sizes up to 36 inches in diameter—

Stamping Press Frame—Rim of Gear Wheels —Steam Engine Cylinder (flange broken)—Steam Engine Cylinder—Cast Iron Flange on Cable Drum for Holding Engine—Frame for Hoisting Engine.

OBJECTIVE—To use judgment and exercise ingenuity in preheating—Involving preheating in advance of welding—And reheating after the job is welded, so as to take care of any ill effects resulting from rapid cooling.

AUXILIARY INFORMATION—The use of various devices such as carbon blocks, carbon paste, etc., to support the molten weld metal and reduce the expense of finishing and cost of the work.

EXERCISE XII

Locomotive Cylinder—Spoke in Fly Wheel —Gear Wheel (broken in rim)—Auto Cylinder Head (head not removable)—Steam Chest—Spoke or Hub in Large Fly Wheel (made in halves)—Steam Hammer Cylinder—Sheave Wheel (broken in halves)—Gear Wheel (broken in halves)—Patch on side of Sprocket Case (for Loco Stoker)—Steam Cylinder Head for Air Compressor (center broken out including stuffed box)—Heater Sections (C. I. heating boilers)—Locomotive Valve Chamber (studs broken out of both ends at bottom)—Locomotive Cylinder (piece broken out of front end)—Locomotive Cylinder (cracked in bottom)—Large C. I. Press Frame—Auto Crank Case where opportunity to machine parts is not at hand.—Auto Cylinder Jacket (crack close to bore).

OBJECTIVE—To weld any weldable job in cast iron.

AUXILIARY INFORMATION—(a) Instruction on the selection of the most improved pre-heating methods—(b) Application of principles and methods of mechanical expansion—(c) Instruction as to the placement of the job during the preheating, so as to eliminate unnecessary handling during the welding process—(d) The necessity of anticipating all conditions and operations necessary to complete the job. **Miscellaneous:** While the welding of cast iron is practically all in the field of salvage work, it may be necessary in some of the work for the welder to be able to read elementary blue prints or shop sketches.

EXERCISE XIII

Cutting ¼ inch Plate—Cutting ½ inch Iron Rod—Cutting Off ½ inch to 1 inch Material—Cutting Flat Sheet ¼ inch to 2 inch to line—Cutting Nuts Off of Bolt without damaging bolt threads (1 inch to 4 inches diam.)—Cutting Angle Iron, Tee Rail Channel Iron and I-Beam—Cutting Flat Sheet ¼ inch by 2 inches—Cutting Flat Sheet ½ inch by 2 inches.

OBJECTIVE—To manipulate torch in cutting steel.

AUXILIARY INFORMATION—Recognition of different grades of steel by the action of the torch and knowledge of their respective cutting properties—(b) Methods and devices for the protection of the welder and others from flying sparks and molten metal—(c) Methods of protecting the hose and apparatus from injury by heat, flying sparks and molten metal.

EXERCISE XIV

Cutting Rivet and Bolt Heads—Cutting Up Scrap Tank—Follow line (sheet rusty on one side and painted on other side)—(Explain about gas or oil tank)—Cutting Bar Iron (4 in. by 4 in.)—Cutting out Hole for Patch side of Tank, $\frac{3}{16}$ inch sheet rust on one side and paint on other—Cutting Hole in ¼ inch Sheet—Cutting Hole in ½ inch Sheet—Cutting 18 inch Circle in ⅜ inch Boiler Plate—Cutting Off 16 inch I-Beam—Cutting Port Hole in Plate (shipwork)—Cutting Hole in Bulkhead for Steam Pipe.

OBJECTIVE—To cut more difficult jobs and do more accurate cutting.

AUXILIARY INFORMATION—Instruction as to dangers involved when cutting tanks which have contained oil or other explosive gases or liquids—Use of tools in laying out work.

EXERCISE XV

Cutting Hole in 1-inch Strap Iron—Broken Stud out of Sheet—Stay Bolt out of outside Boiler Sheet—Stay Bolt out of Fire Box Sheet—Cut Flue—Rivets Out of Sheet—Cut Hole in Side-Rod—Clevis in Side-Rod—Pipe (cut off or cut open for L or T).

OBJECTIVE—To cut steel more accurately and without injuring adjacent parts.

AUXILIARY INFORMATION—Use of rivet-cutting tip—Recognition of different kinds of rivets. **Miscellaneous:** Methods for laying out work using scribing devices such as straight edge, etc.—Methods for laying out pipe intersections.

EXERCISE XVI

Cutting out Link—Cutting Broken Brake Hanger Pin out of Loco Frame—Cutting Steel Shaft 6 inches in diameter—Cutting Sheet to Patterns (Shipwork)—Cutting Locomotive Frame for Weld with Oxy-acetylene —Cutting Locomotive Frame for Weld with Thermit—Cutting Large Gate from Steel Casting 16 inches to 20 inches in diameter—Cutting Cast Iron 1 inch thick—Cutting Cast Iron 3 inches thick.

OBJECTIVE—To cut more difficult jobs, including cast iron and all other ordinary cutting jobs in oxy-acetylene cutting.

AUXILIARY INFORMATION—The use of oxygen and acetylene manifolds—Dangers connected with the use of manifold—Necessary protection of operator when cutting off heavy pieces—Differences between cutting cast iron and steel due to cutting rate, presence of graphite, wider kerf, greater expense, and the use of different tips and pressures. **Miscellaneous:** Cutting cast iron is more of a melting operation than in the case of steel.

EXERCISE XVII

Whistle Lever Holes up to ½ inch in diameter—Steel Rods up to ⅜ inch in diameter—Auto Brake Lever—Shift Lever—Brake Rods (auto or truck)—Build Up Steel Valve Stem —End of Lathe Dog—Handle on Tongs.

OBJECTIVE—To be able to make a simple weld in steel.

AUXILIARY INFORMATION—Recognition of different kinds of steel. **Miscellaneous:** General effect of heat on steels including their fusing points.

EXERCISE XVIII

Trailer Guide (build up where worn)—Angle Iron 4 inches x 4 inches—Filling Up Holes up to ⅝ inch thickness—Round Rods up to 1 inch in diameter—Deck Collar—Automobile Fenders—Wrought Iron or Steel Pipe up to 6 inches in diameter—Side Rod Grease Cup.

OBJECTIVE—To be able to weld more accurately and handle more difficult welding jobs.

AUXILIARY INFORMATION—More complete information as to auxiliary information mentioned above.

EXERCISE XIX

Spool for Brake Hanger (build up worn side)—Truck Bolsters and body Bolsters—Foot on Pilot Brace—6 inch Pipe at right angles making T, 90° elbow or 45° elbow—Hatch Frame (ship work)—Engine Fly Guard (fly wheel) Auto Truss Rods, Fender Brackets and Pedals—Pressed Steel Oil Pan—Plug in Hole in Guide Bar—Dipper Latch (where worn)—Steam Shovel—Holes in Brake Hanger (build up worn places)—Whistle Lever—Reverse Lever Latch (where worn)—End on Locomotive Frame for pilot extension—Steel Barrels and other steel containers up to ⅛ inch thickness (not pressure containers—New metal on Stoker Sprocket Wheel where worn.

OBJECTIVE—To be able to handle a torch in more difficult welding and apply the principles of steel welding to more difficult jobs —Students should know the proper tip to use for the particular welding job.

AUXILIARY INFORMATION—(a) Necessary free distance to take care of shrinkage when welding long seams—(b) Use of jigs

or fixtures in welding barrel seams—(c) Methods of marking different welding rods and necessity for keeping rods of each kind separate—(d) working properties of different welding rods under the torch. **Miscellaneous:** (a) Chemical composition and general quality of different welding rods, together with reasons for their particular composition to meet certain requirements in welding—(b) Effects of chemical composition, heat and mechanical treatment upon physical properties of welds made with different kinds of rods.

EXERCISE XX

Teeth in Quadrant—Automobile Frame—Trailer Yoke (center hole worn too large)—Valve Yoke (build up stem where worn) Hole in Super Heater Unit Pipe—Open Tanks up to ¼ inch thickness—Pressure Vessels up to ¼ inch thickness—High Strength Materials on Structural Steel and Rods up to 3 inches in diameter.—Build up Collars on Truck Axles—Small Locomotive Frames up to 4 inches x 4 inches (two man job)—Joint of Super Heater Unit (where cut out by steam)—Frame Cross Brace—Crack in end of Super Heater Unit—New Joint on Super Heater Unit—Teeth in Steel Gear—End on Quadrant—New Metal on Guide Bar (where worn).

OBJECTIVE—To be able to weld more difficult jobs including small pressure vessels.

AUXILIARY INFORMATION—(a) Importance of using the proper base metal for pressure vessels and the selection of the proper welding rod—(b) Instruction in working methods necessary for safety to welder as well as instruction in precautions which should be taken to prevent failure of tank when placed in service.—(c) Necessity for appreciation on the part of the welder of his responsibility to make the weld as strong as it is possible to make it to protect life and property—(d) Appreciation on the part of the welder of his own limitations and that he should not attempt jobs which can not be safely welded or that are beyond his individual capacity.—(e) Knowledge of the A. S. M. E. Code of Unfired Pressure Vessels and other Federal, State, or local regulations affecting pressure vessels. **Miscellaneous:** (a) Reasons why oils or explosive gases in tanks are dangerous in welding operations—(b) Precautions which must be taken to avoid danger of explosion when welding—(c) Instructions as to proper design and construction of tank—(d) Inspection and testing of welds and finished tank—Necessity and methods of inspection and test—(e) Further scientific principles mentioned in No. 39.

EXERCISE XXI

Key Hole in Valve Stem (fill up where worn too large) Crack in Side Sheet (Loco Fire Box) Trailer Yoke (broken in halves) End Dipper Hanger, Steam Shovel—Mud Ring (cracked in corner) Intermediate Deck Casting (cracked)—Seam in Fire Door Hole—Build up Flange on Loco Driver Wheel Tires—Mud Ring (build up over rivet holes—Driver Box (cracked thru top)—Pedestal Jaws (build up where worn)—Building up lugs on pedestal Jaws where worn—Spoke in Main Driver Wheel—⅝ inch Pressure Vessels.

OBJECTIVE—To be able to weld more difficult jobs and jobs involving greater responsibility, including pressure vessels up to ⅝ inch metal.

AUXILIARY INFORMATION—(a) Instructions in the provisions of Interstate Commerce Commission and A. S. M. E., Federal Steam Boat Inspection, local regulations, State regulations, and insurance company regulations relative to boiler inspection and welding—(b) Necessity of consulting with insurance inspector before beginning work on repairing of boiler or pressure tanks. **Miscellaneous:** More advanced information as outlined above.

EXERCISE XXII

Locomotive Frame larger than 4 inches x 4 inches—Side Truck Frame—Patch on Loco Fire Box side sheet—Rail Ends, Frogs and Switches—Patch in Flue Sheet (broken between bridges)—New Sheets in Fire Box and new fire boxes—Build up Flat Spot on Loco Drive Wheel—High Speed Steel Cutting Lip on Lathe Tool—Patch in Boiler (side sheet pitted or mud burnt)—Cross Head (cracked thru wrist pin hole)—Cross Head (cracked thru piston fit)—Broken Guide Yoke—Gas Engine Crank Shaft (emergency repair job only).

OBJECTIVE—To be able to weld all ordinary and some unusual jobs in steel or iron.

AUXILIARY INFORMATION—Further practical applications of principles stated above. **Miscellaneous:** Further instruction as to kind of rods to be used for specific welds—For example, the advisibility of using manganese steel rods for welding frogs and switches.

EXERCISE XXIII

Lug on Inlet Manifold—New Flange on Manifold—Shorten or Lengthening manifold—Broken Crank Case Bearing (bushing support) Aluminum Steering Wheel—Aluminum Steering Wheel—Aluminum Fenders—Aluminum Crank Case (preheating) (crack in body) Aluminum Transmission Case—Aluminum Water Pump—Crank Case where broken through side or with piece broken out—Sheet Aluminum—Aluminum Tubing.

OBJECTIVE—To be able to make a satisfactory weld in any ordinary job involving sheet or cast aluminum.

AUXILIARY INFORMATION—(a) Operating methods when welding aluminum with and without flux—(b) Comparison of the working properties of aluminum with other metals in welding with reference to the following: 1. Impossibility of relying upon its color as a means of knowing when the metal is at its fusing point—2. Lack of tensile strength of aluminum when heated—3. Necessity for welder using welding rods of proper quality, specially prepared for aluminum welding. **Miscellaneous:** (a) Differences in manufacturing methods involving the following: 1. Use of aluminum-copper alloys for construction purposes—2. Use of aluminum-zinc alloys—3. Use of other alloys—4. Action of the flux on the melted or hot aluminum—5. Oxidization of aluminum and its alloys as compared with oxidization of other metals, both when in cold or heated conditions—6. Selection of proper welding rods to secure stiffness or to assure ductility in welded part.—(b) Physical properties of aluminum including lightness, brittleness, strength, heat, conductivity and hardness—(c) Chemical properties including resistance to acid and alkalis—(d) Effect in aluminum produced by preheating including local and general pre-heating.

EXERCISE XXIV

Small Malleable Iron Casting (not requiring lining up)—Rivets on Rear Axle (Ford housing)—Support Arms on Ford Crank Case Pans—Transmission Case—Auto Rear Axle housings—Journal Boxes where cracked—Agricultural Implements (parts)—Lug on Pipe Vice—Motor Cycle and Bicycle Frames with bronze—Auto Cylinder with bronze.

OBJECTIVE—To be able to weld any ordinary job in malleable iron.

AUXILIARY INFORMATION—(a) Recognition of malleable iron by appearance, grinding, action under torch and chipping—(b) Difference in appearance between malleable iron, cast iron and cast steel—(c) The effect of melting malleable iron with the torch—(d) The effect of bringing to red heat the torch—(e) Recognition of stock white-heart and black-heart malleable iron. **Miscellaneous:** (a) Methods of manufacture of malleable iron—(b) Reasons for using manganese bronze, tobin bronze, and similar alloys for welding malleable iron—(c) Preparation of specific malleable iron job—(d) Use of Vee blocks, surface gauge and clamps for such jobs as rear axle housings—(e) Reasons for the use of special tools for special jobs.

EXERCISE XXV

End on Globe or Gate Valve Stem—End of Valve Stem (build up end for new fit)—Sand Hole in small Casting—Crack in Glove Valve Body—Small Brass Levers and Handles—End on Glove Valve Bonnet—Small Brass Castings broken or cracked—Hole in Feed Pipe—Copper Pipe at Splice—Copper Heater Coils—Brass Water Heater Segments.

OBJECTIVE—To be able to weld simple jobs in copper and its alloys.

AUXILIARY INFORMATION—(a) Difficulties encountered in recognition of stock in order to know its properties due to: 1. Similarity in appearance of different copper alloys—2. Lack of simple tests—(b) Simple tests which may give some information as to kind of stock—1. Presence of zinc determined by torch—2. Hardness determined by drilling or by chipping—3. By inspecting the color of freshly cut surface—4. By its bending qualities—5. By the use for which the part has been constructed—(c) Physical effects on welder and others from breathing of zinc-oxide fumes from brass alloys. **Miscellaneous:** Elementary instruction in the following: (a) Physical qualities of different copper alloys—(b) Physical qualities of copper—(c) Chemical composition of copper and its alloys—(d) Effect of heat and mechanical treatment on copper and its alloys—(e) Difference between brazing and welding—(f) Proper chemical composition of welding rods for copper and its alloys—(g) Reason for use of flux in welding copper and its alloys.

EXERCISE XXVI

End on Line Check Valve—Cross Head Gib (lug broken off) or add metal to take up end ply—Crack in Lubricator Body—New Metal in Hole for lubricator filler plug (threads stripped out) Barrel of test Pump to Base (brass).

OBJECTIVE—(a) To weld jobs where heavy strains are encountered and jobs involving greater difficulty than in the proceeding checking level.

AUXILIARY INFORMATION—Kind of jobs requiring preheating and cooling and instruction in the best methods—(b) Precautions to be taken when welding closed vessels. **Miscellaneous:** Further instructions in the principles given above.

EXERCISE XXVII

Crack in Injector, or Lubricator, or Condensor Body—Bronze Impeller for Centrifugal Pump—Auto Water Circulating Pump—Copper Air Chamber for Water Pump, bursted from overpressure—End Joint on Injector Steam Pipe—Patch on Copper Branch Pipe—Bronze Propeller Tip—Build up Engine Brasses—Fill Shrink Hole in Bronze Propeller—12 inch Brass Flange on Copper Pipe—Whistle Bell (cracked) Crack in Locomotive Bell—Up Steam Valve Seat in Injector—Bell for Safety Pop (cracked)—Brass or Bronze Grids having broken or cracked members (or similar restrained welds)—Very heavy and large Brass Castings such as certain types of Diesel Engine Cylinder Heads or other large copper alloy castings.

OBJECTIVE—To weld any ordinary copper or brass job.

AUXILIARY INFORMATION—(a) Application of the information suggested above to more difficult jobs—(b) Instruction as to the difficulties encountered in welding copper and its alloys, and types of jobs which should not be attempted—Appreciation on the part of the welder that he is not expected to weld every job brought to him, but only those where there is reasonable possibility of doing satisfactory work. **Miscellaneous:** Explanation of principles mentioned in above as far as possible within the capacity of the student.

Training Course for Electric Arc Welding Operators

LESSON 1

SUBJECT: **Electric Arc Welding.**

History—Electric Arc Phenomena—Utility of the Electric Arc for Welding Purposes—Difference between Direct Current and Alternating Current Electric Arc Welding—Carbon Arc Welding—Safety Precautions.

REFERENCE READING — **Encyclopedia Section:** Benardos Process—Eye Protection. **Arc Welding Chapter:** Introduction—The Arc Welder and Its Uses—Carbon Arc Welding—Protecting the Operator—Protecting the Workmen.

LESSON 2

SUBJECT: **Electrical Circuit—The Electric Arc.**

Setting Up Apparatus—Adjusting Current—Care of Apparatus—Locating Trouble.

REFERENCE READING—**Arc Welding Chapter:** Introduction—The Arc Welder and Its Uses—Metal Electrode Welding—Locating Trouble in the Arc Welder—Oxidation within the Arc.

LESSON 3

SUBJECT: **Types of Welding Machines.**

Westinghouse Generator—Wilson Generator—Lincoln Generator—General Electric Generator—U. S. L. Generator—Siemund Wenzel Generator—The Alternarc Transformer—Zeus Transformer. American Welding Society Standardization Rules.

REFERENCE READING—**Arc Welding Chapter:** Electric Arc Welding Machines—American Welding Society Standardization Rules for Electric Arc Welding Apparatus.

LESSON 4

SUBJECT: **Preparation for Welding**

Beveling—Designs of Joints—Jigs—Alignment.

REFERENCE READING — **Encyclopedia Section:** Alignment—Beveling—Butt Weld—Caulking Weld — Corrugated Weld — Composite Weld—Concave Weld—Design of Weld—Fillet Weld—Flush Weld—Jigs—Lap Weld—Plug Weld—Position of Weld—Reinforced Weld—Strap Weld—Strength Weld—Tack Weld—Tee Weld. **Arc Welding Chapter:** Metal Electrode Welding. **Charts and Tables:** Preparation of Parts to be Welded—Nomenclature of Welded Joints in Plate and Angle Work.

LESSON 5

SUBJECT: **Procedure.**

Striking the Arc—Holding the Arc—Position of the Electrode—Arc Manipulation—Beading — Tacking — Weaving—Spreading—Padding—Filling Sequence.

REFERENCE READING — **Encyclopedia Section:** Beading — Padding — Spreading — Tacking—Weaving. **Arc Welding Chapter:** Striking the Arc—Holding the Arc—Filling Sequence.

LESSON 6

SUBJECT: **Selection of Electrodes.**

REFERENCE READING — **Encyclopedia Section:** Welding Rods and Wire. **Arc Welding Chapter:** Introduction.

LESSON 7

SUBJECT: **Welding Rolled Steel and Wrought Iron**

REFERENCE READING—**Arc Welding Chapter:** Arc Welding Applications—Welding of Rolled Steel and Wrought Iron.

LESSON 8

SUBJECT: **Welding Cast Steel**

REFERENCE READING—**Arc Welding Chapter:** Arc Welding Applications—Welding Cast Steel.

LESSON 9

SUBJECT: **Welding Malleable Iron**

REFERENCE READING—**Arc Welding Chapter:** Arc Welding Applications—Welding of Malleable Iron. **Encyclopedia Section:** Malleable Iron.

LESSON 10

SUBJECT: **Welding Cast Iron**

Studding—Grooving—Selection of Electrode Material—Applications.

REFERENCE READING — **Encyclopedia Section:** Cast Iron—Locomotive Cylinders—Grooving. **Arc Welding Chapter:** Applications of Arc Welding—Welding Grey Iron—Miscellaneous—Studding—Arc Welding of Cast Iron.

LESSON 11

SUBJECT: **Welding Non-Ferrous Metals**

Aluminum—Brass—Bronze—Copper—Monel Metal.

REFERENCE READING — **Encyclopedia Section:** Monel Metal. **Arc Welding Chapter:** Arc Welding Applications—Copper—Bronze—Brass—Aluminum.

LESSON 12

SUBJECT: **Welding Manganese Steel**

Electrode Material—Polarity—Arc Manipulation — Water Toughening — Hammering — Welding Procedure—Finishing.

REFERENCE READING — **Encyclopedia Section:** Manganese Steel Welding.

LESSON 13

SUBJECT: **Carbon Arc Welding**

REFERENCE READING—**Arc Welding Chapter:** The Arc Welder and Its Uses—Carbon Electric Welding—Arc Welding Applications—Welding of Gray Iron—Expansion and Contraction—Arc Welding of Cast Iron.

LESSON 14

SUBJECT: **Electric Arc Cutting**

Sheets—Blocks—Risers—Rivets.

REFERENCE READING—**Arc Welding Chapter:** Miscellaneous—Electric Arc Cutting.

LESSON 15

SUBJECT: **Automatic Arc Welding**

REFERENCE READING—**Arc Welding Chapter:** Miscellaneous — Automatic Arc Welding.

LESON 16

SUBJECT: **Heat and Mechanical Treatment**

Annealing—Forging—Preheating.

REFERENCE READING — **Encyclopedia Section:** Annealing—Preheating. **Arc Welding Chapter:** Miscellaneous—Forging Arc Welds.

LESSON 17

SUBJECT: **Boiler Welding**

Fire Boxes—Side Sheets—Door Sheets—Knuckle Patches—Crown Sheet Patches—Seams—Mud Rings—Overhead Welding.

REFERENCE READING—**Arc Welding Chapter:** Miscellaneous—Overhead Welding. **Boiler Welding Chapter:** Boiler Welding with the Electric Arc. **Rules and Regulations:** A. S. M. E. Code; Lloyd's Register of Shipping; Steamboat Inspection Service; State Rules.

LESSON 18

SUBJECT: **Pipe Welding**

Advantages of Welded Pipe Joints—Gas Pressure Pipes—Steam Pipes—Small Pipes.

REFERENCE READING — **Encyclopedia Section:** Pipe Welding—Refrigerator Machinery. **Pipe Welding Chapter.**

LESSON 19

SUBJECT: **Tank Welding**

Storage Tanks — Pressure Tanks — Large Storage Tanks—Rectilinear Tanks—Transformer Tanks.

REFERENCE READING — **Encyclopedia Section:** Back Step Welding. **Arc Welding Chapter:** Metal Electrode Welding. **Tank Welding Chapter:** Electrically Welded Tanks. **Charts and Tables:** Preparation of Parts to be Welded—Nomenclature of Tank Joints.

LESSON 20

SUBJECT: **Rail Joint Welding**

Lincoln Process—Indianapolis Process—Metallic Electrode Process.

REFERENCE READING—**Chapter on Rail Joint Welding.**

EXERCISE I

Setting Up Apparatus—Striking the Arc and Holding the Arc.

Objective: To properly set up the Apparatus for Welding—To strike the Arc—To Hold the Arc long enough to deposit some metal.

Auxiliary Information: Welding Machines are usually shipped with all connections marked. Wiring diagrams of external connections are a part of every machine. Students should learn the name of each part and each terminal. Caution to use gloves, shields, etc., whenever Arc is to be struck. Caution to make all connections tight so as not to cause overheating an electrode-holder. Best arc length is about ⅛ inch.

EXERCISE II

Laying a Straight Bead parallel to chalk line on plate—Laying a Bead to cover initial marked with chalk on plate—Laying Straight Beads without guide lines.

Objective: To control the Arc and lead it in a pre-determined direction.

Auxiliary Information: Holding too long an Arc results in burning, or oxidizing of the metal, and poor penetration—Holding too short an Arc results in freezing of the electrode. Wire must be fed downward as arc advances.

EXERCISE III

Filling in between rows of Parallel Beads.

Objective: To fill in between rows of parallel beads—Securing penetration with the beads already laid and with the parent metal.

Auxiliary Information: Caution to clean each bead carefully before filling in. Special care must be taken to remove all oxide or slag at edge of beads.

EXERCISE IV

Laying a Spreading Bead on a flat surface.

Objective: To build up on a flat surface a wider deposit than can be made by advancing the arc in a single direction.

Auxiliary Information: Caution not to move the electrode so fast that it cannot form a crater properly and deposit all of the electrode material into the crater thus formed. If a flux covered wire is used, keep the short arc to insure penetration. If second layer is added oxide must be cleaned from first layer.

EXERCISE V

Build up on a flat surface.

Objective: To make a Padding Weld on a flat surface.

Auxiliary Information: Necessity for cleaning each layer before adding the next layer. Good practice demands that a layer covering about 10 sq. inches should be brushed at least three minutes. Running the beads in the second layer at right angles to those in the first layer is called "lacing" and is best practice. It is better to use a hammer and chisel between each layer for cleaning off the oxide than to simply use a brush. The fusion between the pads and

the original plate must be perfect if the weld is to be of any value.

EXERCISE VI

Welding a Car Bolster—Welding a Locomotive Frame—Making a Butt Weld in ½ in. steel plate or heavier—Butt Straps.

Objective: To fill in a beveled Vee which requires the application of more than one bead.

Auxiliary Information: Caution to observe the necessity for penetrating to the very bottom of the Vee, making allowance for expansion and contraction on large pieces. The best results are obtained when welding is done according to a definite pattern and proper Filling Sequence is observed.

EXERCISE VII

Welding a small steel casting with Carbon Arc.

Objective: To use the Carbon Arc and Filler Rod on small steel castings.

Auxiliary Information: On small work requiring 300 amperes, the arc should be held about a quarter of an inch long. Carbon electrode should be sharpened to the point. Necessity for working rapidly so the metal will not be ruined by the extreme heat. If the arc breaks during the operation, it should be started again on solid metal and brought quickly to the welding area. This prevents hard spots. Caution not to play the arc on the fused metal after the hole is filled. Preheating around the weld will prevent too sudden cooling.

EXERCISE VIII

Weld two pieces of ½ in. Boiler Plate, beveled at 45 degrees.

Objective: To make a good weld on Boiler Plate.

Auxiliary Information: Caution to secure thorough penetration. Holding the electrode perpendicular to the surface, makes it easier to maintain a short arc. A long arc can be identified by its sputtering and hissing. When arc is correct length it gives a crackling or snapping sound. The operator should concentrate his attention on the forward edge of the crater. It is possible to make good electric weld only when the molten metal from the electrode flows directly into the molten crater.

EXERCISE IX

Making Butt Weld and Tee Weld on thin plates.

Objective: To be able to weld sheet steel without burning through.

Auxiliary Information: Necessity for cleaning blue oxide off sheets with chisel or sandblast before starting to weld. Using copper plate back of weld to absorb heat gives better results. Greater speed reduces chance of burning through, but penetration must not be sacrificed for speed.

EXERCISE X

Welding a caulking edge on a riveted seam. Weld around the head of a rivet—Weld two pieces of heavy plate together without beveling—Weld an Angle Iron Section.

Objective: To be able to weld miscellaneous jobs.

Auxiliary Information: Repair welding requires a great deal of resourcefulness and natural mechanical ability. The importance of careful preparation and cleaning of the work before starting to weld. The selection of the filler rod. In running a caulking edge bead the electrode should be held half way between the two faces. To weld around a rivet, start arc about ¼ inch from rivet, so perfect fusion will be secured at rivet head, and overlap at finish, holding arc for complete circuit.

EXERCISE XI

Filling in a defective steel casting with the Carbon Arc—Repair broken steel casting with the Carbon Arc.

Objective: To know when to use the Carbon Arc on steel castings, and how to avoid hard spots.

Auxiliary Information: Deep sand holes can be filled in better with the Carbon Arc. All foreign matter should be floated to the surface so it can be worked out before new metal is added. Where there is danger of contraction strains, castings should be preheated. Preheating will also prevent casting from cooling too fast. If the arc is broken, it must not be started again on molten metal. Annealing is recommended to remove strains left in casting. Carbon arc should be used for repair only when it is desired to add metal very fast.

EXERCISE XII

Filling in sand hole in steel casting with Metallic Arc—Repair broken steel casting with Metallic Arc.

Objective: To use the Metallic Arc for reclaiming imperfect castings and repairing broken castings.

Auxiliary Information: Shallow sand holes can be filled in with Metallic Arc. Use carbon arc if possible to float out foreign matter. Welding must be completed with a minimum amount of metal between the fractured edges. Just enough beveling should be done to permit thorough penetration and proper arc manipulation. On heavy work the beveling should be made on both sides of the joint if possible. On complicated and thin sections, welding may have to be carried on intermittently to allow proper heat distribution. Whenever possible, the steel should be reinforced.

EXERCISE XIII

Make a right angle of two pieces of angle iron—Weld a truss of angle iron—Weld channel iron to sheet—to stiffen.

Objective: To be able to weld Structural Steel.

Auxiliary Information: Caution to make the weld penetrate all sections evenly. Many of these welds can only be made from one side of the work. In many cases it is necessary to make a Strength weld. Operator will have to be familiar with blueprints and know how to follow them.

EXERCISE XIV

Weld longitudinal seam in small tank—Weld head in small tank—Weld 6 ft. lap and butt seams on quarter-inch plate—Weld angle iron to quarter-inch plate—Weld nipple on small tank—Weld rectangular tank.

Objective: To be familiar with all types of welds in tank construction—To be able to weld fittings on tank—To recognize the various types of tank joints and select the type of joint best fitted for the construction to be made.

Auxiliary Information: On production work, jigs for handling the material will make welding easier and reduce the time of construction. Where Butt Joints are to be made, plates heavier than ¼ inch plate should be supplied already beveled. Different kinds of welds will be required depending on the nature of the strain. Allowance must be made for contraction on long Butt seams. See chapter on "Tank Welding" and "Charts."

EXERCISE XV

Make Butt Weld in small diameter pipe—Butt Weld in large diameter pipe—Tee Welds and Angle Welds in small and large diameter pipes—Make Manifold by welding small pipe to large pipe.

Objective: To be able to make Butt, Tee and Angle Welds in pipes of large and small diameters.

Auxiliary Information: Caution to use care in selection of electrode material, particularly when the construction is for pressure. It is good practice to build on a good reinforcement on pipe welds. The surface that is to be welded must be clean and the operator must hold a short arc. All pipe welds should be tested for leaks, if possible. Pipe welding is one of the most difficult welding operations.

EXERCISE XVI

Weld Separator Tank—Weld headers and manifolds—Weld Condensers for Pressure

Still—Make Pressure Tank by Welding heads and nipples on 24-inch pipe.

Objective: To be able to make satisfactory welds on Pressure Work.

Auxiliary Information: Caution to secure thorough fusion and penetration, and to work always on clean metal. Operator should be familiar with rules for welding in the A. S. M. E. Boiler Code, Rules of the Steamboat Inspection Service, of Lloyd's Register of Shipping, as well as State and Local Regulations regarding the welding of pressure vessels. Caution to remove all oil from pipe.

EXERCISE XVII

Weld Flue to Flue Sheet—Weld Fire Box sheet knuckle patch—Weld cracked side sheet—Weld patch on front of crown sheet—Weld broken mud ring—Weld patch on door collar—Make overhead weld in boiler.

Objective: To be able to make repairs on boilers by welding.

Auxiliary Information: When welding flues play heat mostly on flue sheet. Operators should be familiar with rules as outlined in previous exercise. Electrode material must be carefully selected for boiler work. For good results, it is necessary to take plenty of time to clean the metal until it is bright. 20 per cent reinforcement on the fire side and 10 per cent reinforcement on the water side is recommended, especially on the crown sheet. Welding from the bottom upwards is recommended on side sheets. Applying too much metal will result in cracks due to overheating. Bevel cracks before welding.

EXERCISE XVIII

Weld a cast iron boiler section with the Carbon Arc—Weld a cast iron fly-wheel with the Carbon Arc—Weld a cast iron planer bed with the Carbon Arc—Weld a locomotive cylinder with the Carbon Arc.

Objective: To be able to make cast iron welds with the Carbon Arc.

Auxiliary Information: Necessity for preheating cast iron welds before welding with the Carbon Arc. Cast iron welds should be allowed to cool slowly. Caution not to play the arc on the weld any longer than is necessary to give complete fusion. Caution to break the arc and allow weld to cool slowly if the metal gets too hot and runs badly.

EXERCISE XIX

Weld a Cast Iron Boiler Section with the Metallic Arc—Weld a Cast Iron Fly-wheel with the Metallic Arc—Weld a Cast Iron Planer bed with the Metallic Arc—Weld a Locomotive cylinder with the Metallic Arc.

Objective: To be able to make cast iron welds with the Metallic Arc.

Auxiliary Information: Caution to make careful study of the requirements for size and location of studs when they are used. Cast iron electrode can be used without studs if the parts are preheated before welding. In welding cast iron with studs preheating is not necessary but preheating is recommended for best results on all cast iron welds.

EXERCISE XX

Build up worn Manganese Frog—Build up worn Manganese Crossing—Build up worn Conveyor Bucket Lip—Build up worn Dredge Tooth.

Objective: To be able to build up worn surfaces on Manganese and high carbon steel.

Auxiliary Information: This type of welding must progress slowly to prevent overheating of parent metal. Operator should learn to avoid sharp humps or low spots. The arc should be protected from air draughts. See "Manganese Steel."

EXERCISE XXI

Weld copper bonds to car rails—Weld bronze Propeller Shaft Sleeve—Weld Seams in Monel Metal Tank.

Objective: Make welds on nonferrous metals.

Auxiliary Information: Bronze containing even a relatively small proportion of zinc is very difficult to weld. Aluminum and brass cannot be successfully welded with metallic arc. See "Monel Metal."

EXERCISE XXII

Cut heavy plate with Carbon Arc—Cut Cast Iron Section with Carbon Arc—Cut rivets out of plates—Cut off Risers.

Objective: To be able to use the Carbon Arc for cutting.

Auxiliary Information: For straight cutting, the limit for economical work is about 5 in. The carbon arc will cut cast iron and non-ferrous metals. Heavy sections can be nicked for breaking.

Examination of Operators

EXAMINATION OF OPERATORS

A better understanding of the requirements of a welding operator for a certain job, will naturally mean that more attention will be given to the training and development of the man selected for it. The employer benefits from a reduction in the labor turnover and the welder benefits by having his abilities better developed for his job. The use of a standard questionnaire of personal qualifications, as listed below, is urged for all welding departments. Every applicant for a welding position should be given an opportunity to answer these 15 questions, and his answers should be made a matter of permanent record. Other questions are given to test the applicant's knowledge of processes, the equipment, and supplies used. Where the work is of a specialized nature, questions are suggested which relate to special jobs. A careful reading of these questions is strongly recommended to the welders themselves. They furnish him an excellent opportunity to test his own ability and his own knowledge of the processes he uses.

QUESTIONNAIRE FOR OXY-ACETYLENE WELDERS

A. Personal Qualifications

1. Name?
2. Address?
3. Phone?
4. Is address permanent?
5. Married or single?
6. Nationality?
7. Are you employed now, and, if not, why?
8. Where did you learn welding? When?
9. What welding experience have you had?
10. What books or magazines on welding do you read?
11. What make or makes of apparatus have you used?
12. What was the largest job you ever welded? The smallest job? What difficulties did you experience?
13. What metal do you prefer to weld? Why?
14. What sort of welding do you consider your specialty?
15. What pay do you expect?

B. General Welding Knowledge

1. Explain method of setting up apparatus, lighting torch, and adjusting flame for cast iron, aluminum, brass, copper, steel. What welding rods and flux for these welds?
2. How does the strength of the weld compare with the strength of the original piece?
3. Should welding be done while the preheating fire is kept going?
4. Why do welders wear goggles?
5. What does the flux do for the weld?
6. What difference does it make whether we clip out the bevel on a heavy casting or melt it out with the torch?
7. How can the common metals be identified?

8. Why cannot malleable iron be welded?
9. What is the melting point of cast iron? Mild steel? Hard steel? Aluminum? Brass? Bronze? Copper?
10. What does annealing accomplish?
11. Why cannot scale or slag be cut?
12. What determines the size rod to use?
13. How do you figure the cost of a welding job?
14. Name three ways to check gas consumption?

C. Equipment

1. What is meant by a low pressure system? Equal pressure? High pressure?
2. Why is it dangerous to use oil on oxygen cylinders, regulators, gauges and fittings?
3. Why should tanks be kept cool in summer and warm in winter?
4. What causes gauges to freeze?
5. What is the temperature of the oxy-acetylene flame?

D. Acetylene

1. What is acetylene?
2. How is it made?
3. Is it poisonous?
4. What does an excess of acetylene do to molten metal?
5. Why can a generator carry only 15 lbs. pressure, when you can obtain quite a higher pressure from the tanks?
6. Why should acetylene tanks be stood on end before and while being used?
7. What are the impurities in this gas?
8. Can other gases be used in place of acetylene?
9. What is likely to happen if there is a leak in the acetylene hose while welding inside of a tank?
10. How fast can acetylene be used from a cylinder?
11. What is acetone.

E. Oxygen

1. How is this gas obtained?
2. Why not use some other gas?
3. How many cubic feet in one pound of gas?
4. Why do metals scale on being heated very hot?
5. What is rust?
6. What really happens when an excess of oxygen is used in welding?
7. Why is so small an amount of liquid required in fire extinguishers?
8. How is the size of the cutting tip determined?
9. What is the use of oxygen in oxy-acetylene welding?
10. Can oxidized metal be restored to its former properties?
11. How does a regulator work?

F. Sheet Steel

1. If work is on sheet steel have the man set it up preparatory for welding.
2. Sizes of tip required.
3. Choice of adding material, flux, etc.
4. Method of welding whether forward, backward, or for strength, finish or what?
5. Method of avoiding stress or strain or distortion in progress of work or afterwards.
6. Can rigid fastening be used to hold pieces in place for welding? Why?
7. Can heat treatment be applied to advantage? How?
8. If on riveted boiler seam does welding finish the job? What should be done then? What test may be used in this case?

G. Heavy Steel Welding

1. How strong can a flush butt end weld be made in reference to the original piece? Why?
2. If added material of greater strength or better quality is used, how does this affect the result of the above?
3. Can an automobile steering knuckle be welded?
4. How can small pieces of tool or alloy steel be welded? Could this be done without drawing the temper, and if so, how strong will it be?

H. Cast Iron

1. How does cast iron differ from steel welding?
2. Can successful cast iron welding be done without flux?
3. Can steel rod be used on cast iron, or vice versa?
4. Can confined sections of cast iron be welded by local preheating? Mention specific cases such as radiator sections or spoked wheels.
5. How to proceed to weld a grate bar. What may be used for flux in this case?
6. If a cast iron piece is warped how can it be straightened?
7. What causes hard spots in cast iron?
8. What causes blow holes in cast iron?

I. Aluminum

1. How is sheet aluminum set up for welding?
2. What may be used for added material?
3. What kind of flux used? (State physical condition, dry or moist, etc.)
4. What mechanical treatment may be performed afterwards if warpage occurs in welding?
5. What flux is used with cast aluminum?
6. Describe advantages of using drawn or cast rods on either drawn or cast aluminum welding?
7. Should preheating be done on cast aluminum locally or generally?
8. Describe method of determining amount of heat necessary for preheating?

J. Brazing Copper, Brass, Etc.

1. Can blow holes be avoided in welding or brazing copper?
2. Would such welding be successful on electroplated copper roll for printing?
3. Can welding rod of greater hardness or higher melting point, be used on copper or brass successfully?
4. Is flux required in welding copper?
5. How many times can a welded or brazed section be melted over, in copper or brass? What results?
6. How are pieces of metal of different nature, usually joined?
7. How about the strength of such a weld?
8. Why is it better to use too large a tip than too small a tip when welding brass?

Tests

1. Have welder take disassembled outfit, set it up, and start the weld, selecting his own tip, adjusting pressure and flame to suit himself, and picking out his own filler.
2. For production work, have working samples, that is, pieces identical with those encountered in production, and apparatus ready. Let him weld two samples. Test to destruction and examine.
3. Have applicant make plain butt weld on plate steel and give bending test.
4. Have applicant weld sample of metal to which he claims to be most accustomed.
5. Have applicant work for two days beside the best welder in the shop.

QUESTIONNAIRE FOR ELECTRIC ARC WELDERS

A. Personal Qualifications

Same as for oxy-acetylene welding.

B. General Welding Knowledge

1. Explain the procedure of setting up apparatus, making connections, and striking arc.
2. How does the strength of the weld compare with the strength of the original piece?
3. When should arc welds be preheated?
4. Why are shields or helmets necessary?
5. What is the purpose of the flux coating on some electrodes?

6. What is the difference between a flux coated elcctrode and a slag coated electrode?
7. Can carbon arc welds be made as good as metallic arc welds?
8. How do you bevel for arc welding?
9. How can the common metals be identified?
10. What are the melting points of the common metals?
11. Why do we anneal welds?
12. How do you figure the cost of a welding job?
13. How do you determine the size of wire and amount of current for each job.

C. Equipment

1. What is the difference between a. c. and d. c. arc welding?
2. Is any more heat supplied to the parent metal in carbon arc welding than in metallic arc welding?
3. Is the welding current dangerous? Why?
4. What is the temperature of the arc?
5. What is the effect of a heavy intermittent load on the power line?
6. How is the arc used for cutting? To what extent?
7. What is meant by "reversed polarity"? When is it used?

D. Electricity

1. What is a closed circuit?
2. Why must the ground connection be kept clean and bright?
3. Why do we reduce the current when we change to a smaller electrode?
4. What effect will a dirty commutator have on the welding current?
5. What is a transformer?
6. What is induced current?

E. Sheet Steel

1. How will you prepare for welding and set up the longitudinal seam in a cylindrical sheet steel tank?
2. What current would you use? What electrode?
3. Method of electrode manipulation?
4. How would you avoid buckling?
5. What is the difference between the rigid and non-rigid systems of welding?
6. How much would you reinforce? Why?
7. How can you test such welds for porosity?

F. Heavy Steel Welding

1. How much beveling is necessary?
2. How would you make bevel?
3. How much would you reinforce?
4. How strong can one of these welds be made?
5. Will preheating do any good? Annealing?
6. What procedure is used for welding alloy steels?
7. How can such welds be improved?

G. Cast Iron

1. Why are studs used?
2. Why are grooves used?
3. Is there any other way to weld cast iron with the arc except by the studding process?
4. How do you overcome the effects of contraction?
5. What causes hard spots in arc welds in cast iron?
6. What causes blow holes?

H. Non-Ferrous Metals

1. Describe a method of arc welding copper.
2. Describe a method of arc welding bronze.
3. Describe a method of arc welding monel metal.

Tests

1. Have applicant set up and connect a disassembled arc welding set, select wire, adjust current and start welding.
2. Have appliance make a tee weld in plate and test the weld to destruction.
3. Reverse the polarity and observe how long it takes applicant to discover what has been done.
4. Have applicant weld a couple of samples of the actual work he will be required to do. Observe difference in speed and quality of both welds.

Discussion of Questions and Tests

It will be found worth while to make the answers to questions in group A a matter of permanent record. This will assist the employer in getting in touch with applicant at a later date, and will also save the trouble of corresponding with applicants who have not had the right experience to qualify for the work which is to be done.

The first seven questions of this group are self-explanatory. Questions regarding the training and welding experience are probably the most vital, and in case of an oral examination these questions should be followed up by more searching questions, the nature of which will depend upon the circumstances. It has been suggested, for example, that a man who has learned welding in a welding school is apt to know a little bit more about the theory than a man who has learned it in the shop, but not so much about the practice. The exact nature of the work previously done by the applicant is also very important. It is not enough, for example, for an applicant to state that he has been welding on pipe, because as one welding supervisor claims, a man who is accustomed to welding on large pipes, such as large oil pipes, would make a failure at first welding on small pipes such as are found in refrigerating machinery. It is also advisable to get complete details regarding the welder's special preference, because he is quite likely to have a method of manipulation which would be very good on one kind of work and not as good on another kind. A questionnaire of this sort, properly used, will make it possible to get better results from new welders right from the start.

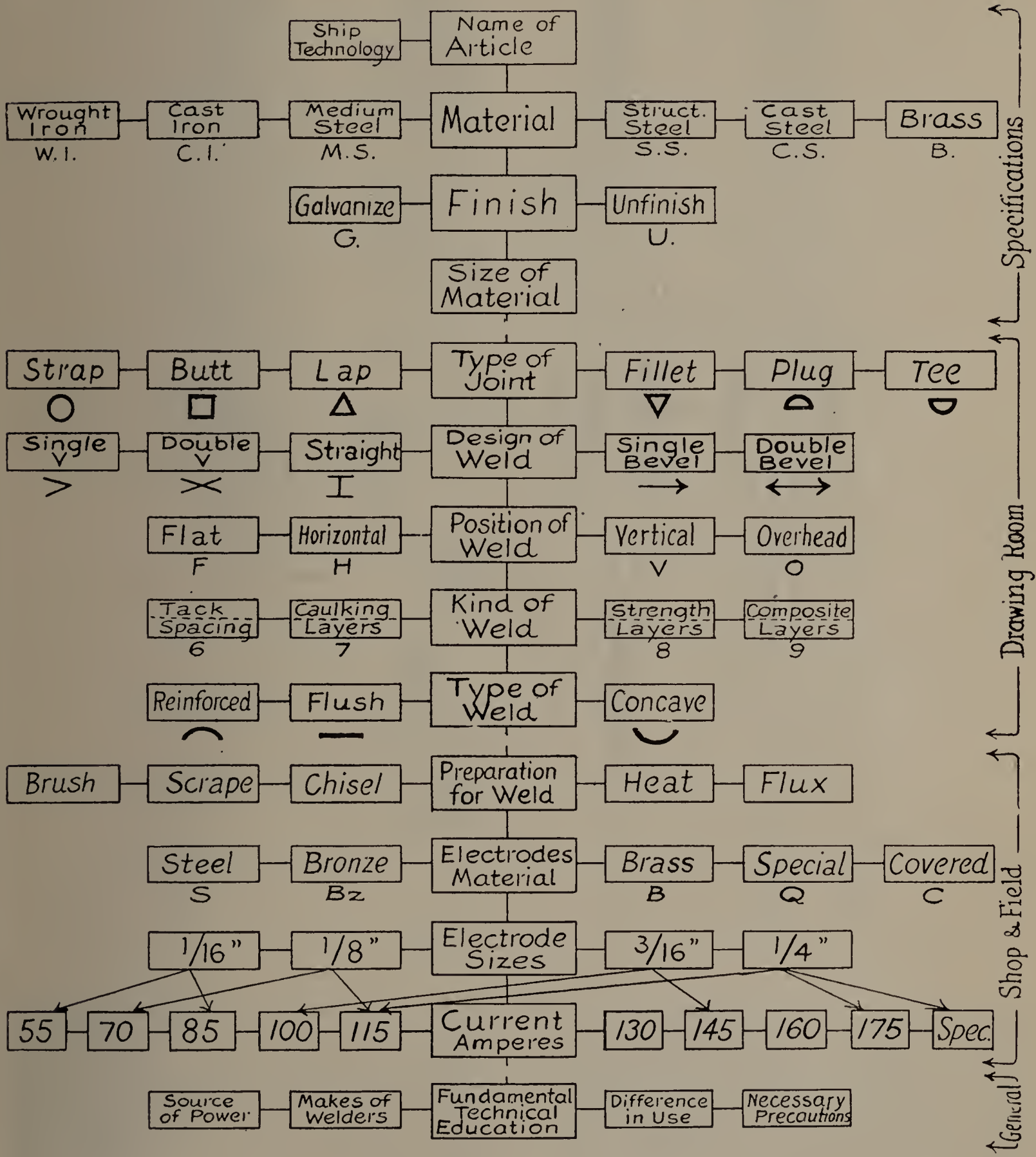
The questions included in the second group under the title, "General Welding Knowledge," are typical questions to be presented to men who apply for positions as foremen or supervisors, or men who are to be given entire charge of welding operations without supervision. It is not suggested that all of these questions be used in the form of a regular examination, but a number of them have been set down here so that the employer can select questions best suited to his problems. The same remarks would apply to the questions dealing with equipment, oxygen, acetylene, etc.

Other sets of questions on the subject of sheet metal, steel castings, cast iron, etc., have also been included, because when the requirements of a position are of a special nature, it is advisable to find out how near the applicant can come to meet those special requirements.

Of the tests suggested, perhaps the most useful consists in having the applicant set up the apparatus himself for welding, and start welding. In going through this procedure, the applicant will always show very clearly just how much at home he feels with the welding apparatus. If a man is to be hired for any very careful work, it is, of course, advisable to have him weld test pieces. In such cases it is better to have the tests made on actual samples of the work which is to be done. These samples can be tested and the welds examined very carefully for penetration, etc.

TABLES and CHARTS

Symbol and Instruction Chart



SYMBOL AND INSTRUCTION CHART

THIS chart was prepared by the Welding Committee of the Emergency Fleet Corporation for the purpose of having a standard set of symbols to use in specifying what welds were to be used, and also to give a sort of birdseye view of the factors to be considered in ordering a welding job. The use of these symbols singly and in combination can be found illustrated in the text under the headings "Butt Weld," "Lap Weld," "Tee Weld," etc.

Steel Testing By Spark Method

The welder is often at a loss to determine the exact quality of a piece of metal, and if a successful weld is to be secured this forehand knowledge is necessary. Mr. John F. Keller, instructor in forging at Purdue University, Lafayette, Ind., has worked out a useful method, which is illustrated in these charts. Accompanying these illustrations, Mr. Keller makes the following observations:

Fig. 1. A piece of wrought iron free from carbon. If held against the emery wheel the end of the bar will be heated by friction; as the small particles are thrown from the wheel they will follow a straight line which becomes broader and more luminous some distance from the source of heat, and then disappear as they started. This is probably due to the action of oxygen of the air on heated particles requiring some time to act.

Note: Touch material lightly on wheel; observe individual spark. Use black background.

Fig. 2. Mild steel which contains a small percentage of carbon. The effect is at once noticeable by a division of forking of the luminous streak; this is owing to the presence of carbon which is acted upon by the maximum heat of the iron spark, which then burns explosively causing a break in the original heavy lines.

Fig. 3. The lower grades of tool steel which contain from 50 to 100 point carbon. The iron lines become less and less conspicuous, the forking of the luminous streak occuring very much more frequent, often subdividing; the lower the carbon the less sparks and further from the source of heat.

Fig. 4. In the higher grades of carbon steels the iron lines are practically eliminated, with an increase of the star-like explosions which often divide and subdivide, causing

HIGH SPEED STEEL 5

MANGANESE IRON OR STEEL 6

MUSH TT STEEL 7

MAGNET STEEL 8

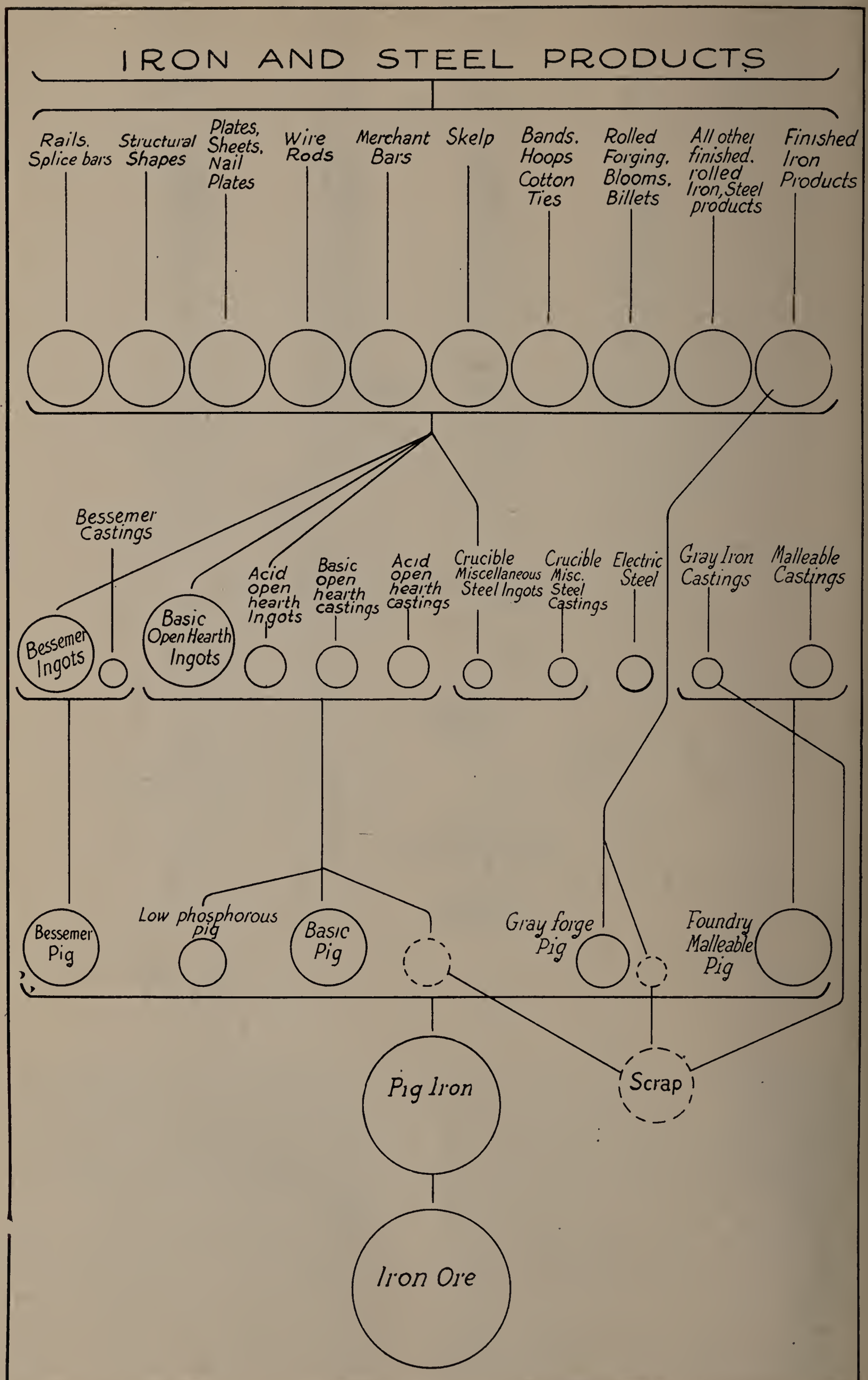
a beautiful display of figures. This is probably due to the iron and carbon becoming so united that they are most easily attacked by the oxygen. Hence the great danger of burning steel in the fire. It would be well to state that the higher the percentage of carbon the more profuse the explosions and the shorter the distance from their source of heat.

Fig. 5. Chromium and tungsten high speed steels are very easily determined by the spark test. The particles seem to follow a broken line with a very slight explosion; just before they disappear the color is of chrome yellow—and show no trace of a carbon spark.

Fig. 6. Manganese in tool steel above a certain per cent is a very injurious element. The characteristic of the manganese spark is that it widely differs from the carbon spark in that it seems to shoot or explode at right angles from its line of force. Each dart is subdivided into a number of white globules. With a little practice the trained eye will soon detect the slightest trace of manganese in the iron or steels.

Fig. 7. Mushett steel, the grade of air hardening or high speed steel. It is very easy to distinguish from other steels as the particles follow a broken line and are a very, very dark red, with an occasional manganese spark.

Fig. 8. Represents the spark as thrown from a special steel manufactured, and to be used especially for magnets. It clearly demonstrates the advantage of this method of selecting steels by comparison; in other words mark your favorite brands or grades and compare them with others. By practicing this method there will be less taps and reamers made out of machinery steel, with a corresponding decrease of forging made out of metals that are too high in carbon.


IRON AND STEEL PRODUCTS
Rails. Splice bars
Structural Shapes
Plates, Sheets, Nail Plates
Wire Rods
Merchant Bars
Skelp
Bands. Hoops Cotton Ties
Rolled Forging. Blooms. Billets
All other finished. rolled Iron, Steel products
Finished Iron Products
Bessemer Castings
Acid open hearth Ingots
Basic open hearth castings
Acid open hearth castings
Crucible Miscellaneous Steel Ingots
Crucible Misc. Steel Castings
Electric Steel
Gray Iron Castings
Malleable Castings
Bessemer Ingots
Basic Open Hearth Ingots
Low phosphorous pig
Bessemer Pig
Basic Pig
Gray forge Pig
Foundry Malleable Pig
Pig Iron
Scrap
Iron Ore

PREPARATION OF PARTS TO BE WELDED

IN the four pages following are illustrated a number of the joints that the welder has to make. It will be noted from the text below that in some cases the parts have been prepared properly and in other cases improperly.

Fig. 1 is a poor method of joining sheet metal. There is very apt to be a layer of oxide in the joint.

Fig. 2 will make a better joint than Fig. 1 but it is inconvenient to prepare the metal this way.

In angular joints like those in Figures 3 and 4, the arrangement shown is more advisable than overlapping as in Fig. 5 or Fig. 9.

Figs. 6. 7, 8 and 10 are further examples of joints that can be made without preparing the parts although Fig. 7 is not apt to prove a strong joint.

Figs. 11 and 12 are the simplest designs for ordinary butt welds. (See "Design of Weld.")

Fig. 13 is a method that should never be used. A good weld cannot be secured this way.

When making a right angle joint between thick plates, Fig. 14 is preferable to Fig. 8.

Two other good methods of making this type of joint are shown in Figs. 15 and 17. Fig. 16 is a very unsatisfactory arrangement.

Fig. 18 will probably produce a better joint than any of the four methods just mentioned.

The methods shown in Figs. 19 and 20 are sometimes used but do not appear to be good practice.

Fig. 21 shows a preparation that will give the strongest joint between three pieces.

Figs. 22, 23 and 24 make a good joint if the work is carefully done but this sort of design requires the use of a great deal of filling material.

If the weld is made as shown in Fig. 26, there is danger of not securing penetration. This danger can be overcome by preparing the parts as shown in Figs. 25 and 27 but welding on a design of this kind should be trusted only to skilled workmen.

Fig. 28 illustrates the beveling necessary when butt welding tubes.

Fig. 29 shows how the weld should be made in the longitudinal seams of tubing.

Fig. 30 is a good arrangement for welding a bottom in a cylindrical tank.

Figs. 31, 32 and 33 illustrate the joining of tubes at right angles.

Figs. 34 and 35 are two other methods of making angle joints in tubing.

Fig. 36 illustrates the use of a specially made flange for tube welding.

Figs. 37 and 38 show two methods of building a flange on the end of a tube. Fig. 37 is probably the better method but the welding will prove more difficult.

Fig. 39 shows the beveling for small round rods.

Fig. 40 shows the beveling for larger rods.

When rods are to be butt welded, the ends should never be turned to a point as shown in Fig. 41.

The seam around the bottoms of tanks can be prepared as in Fig. 42 if they do not have to be very strong.

Fig. 43 is a good method of welding bottoms in gas containers.

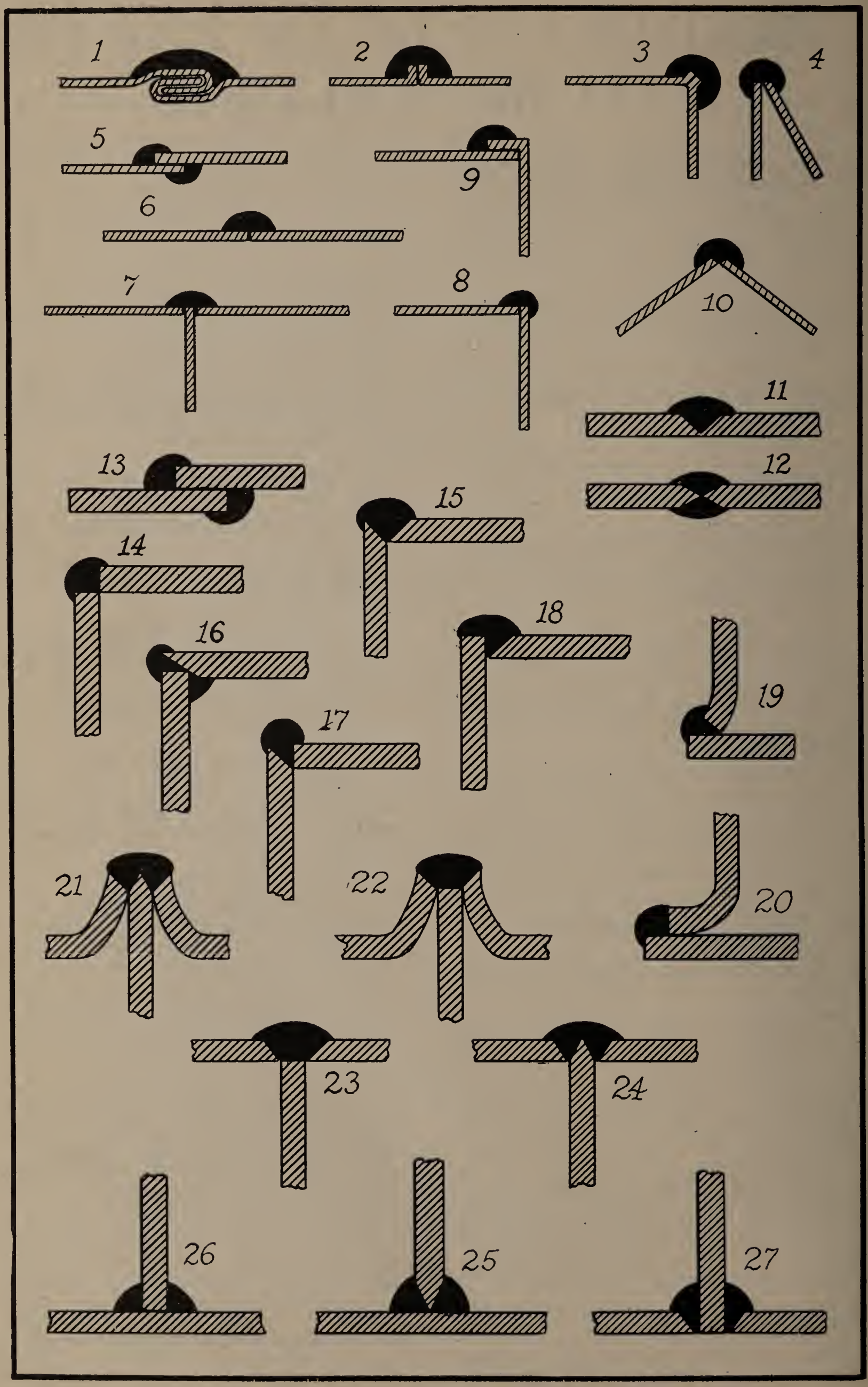
Fig. 44 is a good strong method of welding in a partition.

Figs. 45 and 46 are rather undesirable methods of welding bottoms on cylinders. Fig. 47 is much better. Figs. 48, 49 and 50 are three more undesirable types.

Fig. 51 is simply another illustration of butt welding pieces of the same thickness. If pieces not of the same thickness are to be butt welded, do not use the method in Fig. 52 if it can be avoided for the method shown in Fig. 53 will save filling material and give a better joint provided the operator is careful to manipulate his torch so that both pieces are melted at the same time.

Fig. 54 shows the use of a wedge in welding cylinders in order to keep the edges properly separated. If the seams are tacked before the welding starts, the cylinder will be distorted in Fig. 56. Fig. 55 shows a distortion that is apt to take place when bottoms are welded in cylinders.

Fig. 57, 58 and 59 show what takes place when sheets are butt welded with the edges parallel at the beginning of the operation. The sheets first separate a little then drawn together and finally overlap. This can be overcome by separating the sheets as in Fig. 60 or by tacking them in Fig. 61. (See "Sheet Metal Welding.")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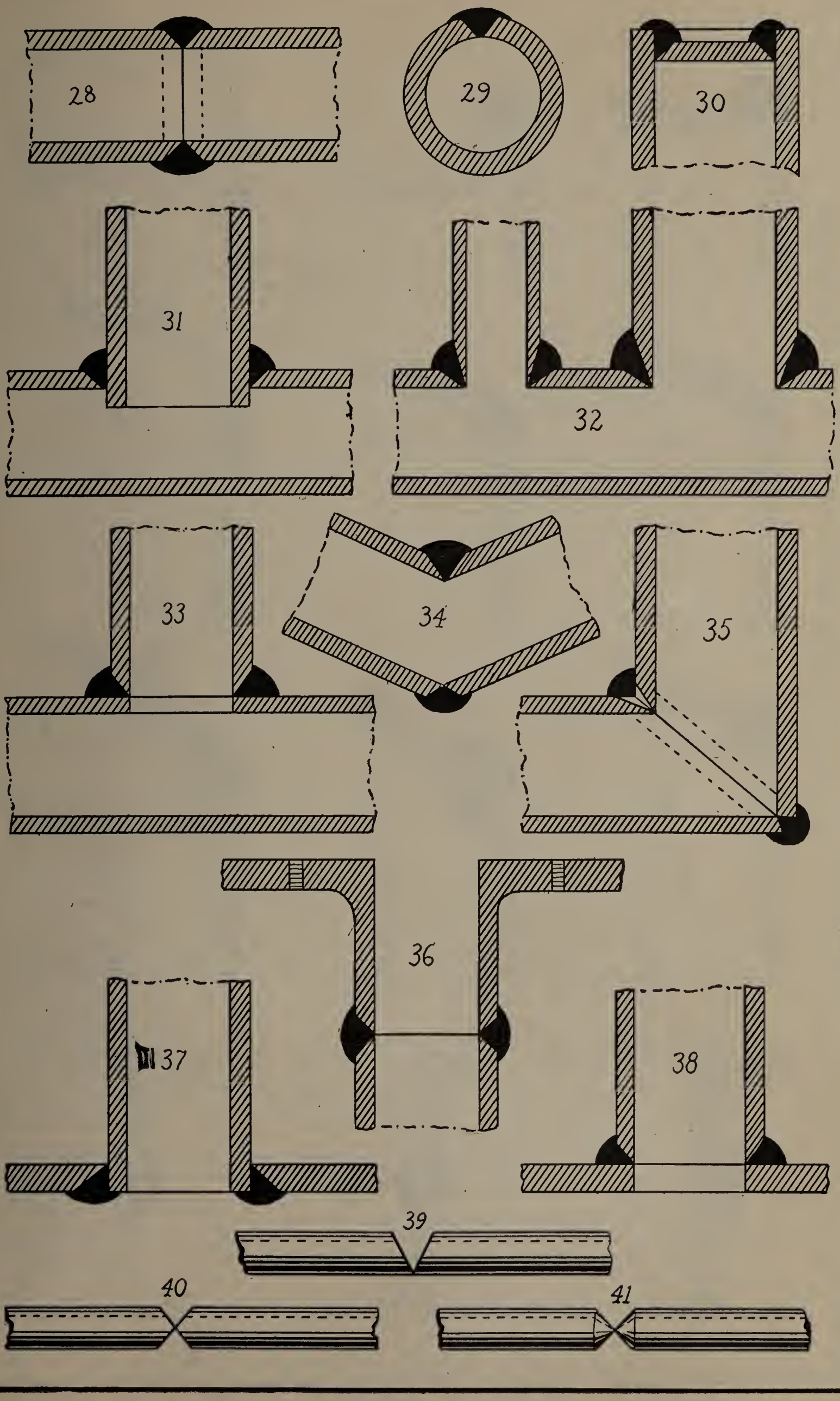
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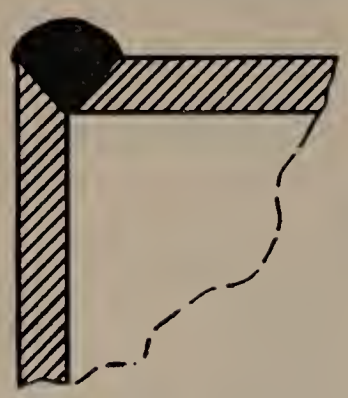

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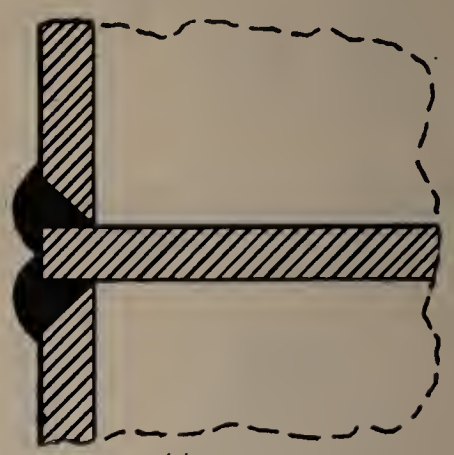

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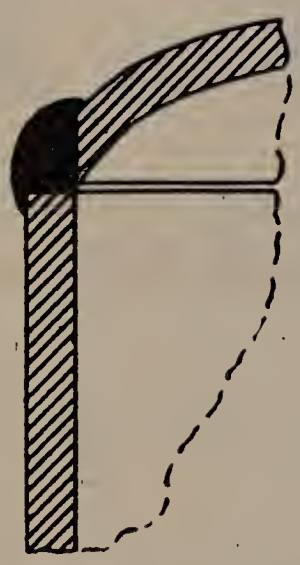

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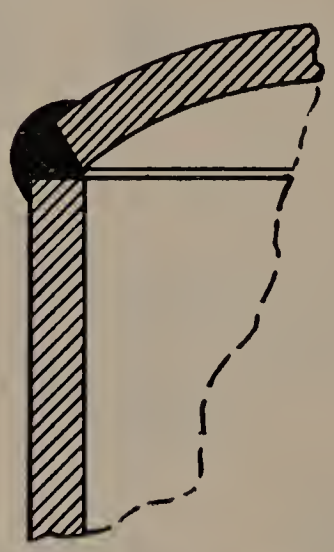

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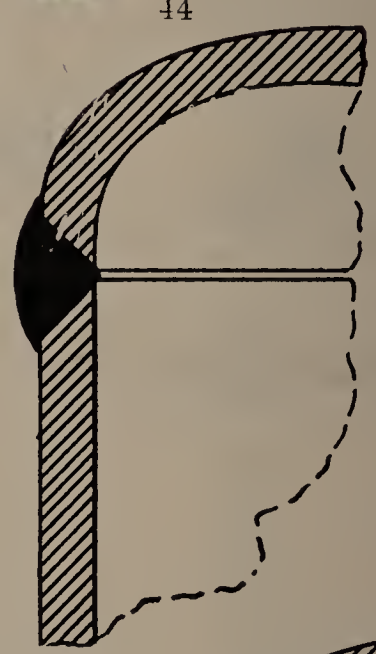

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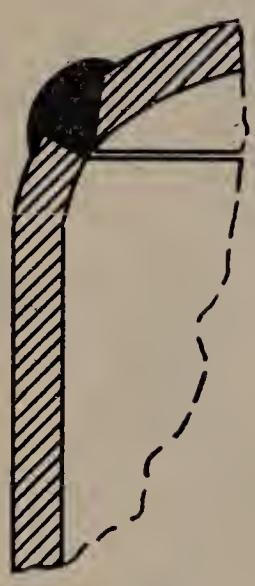

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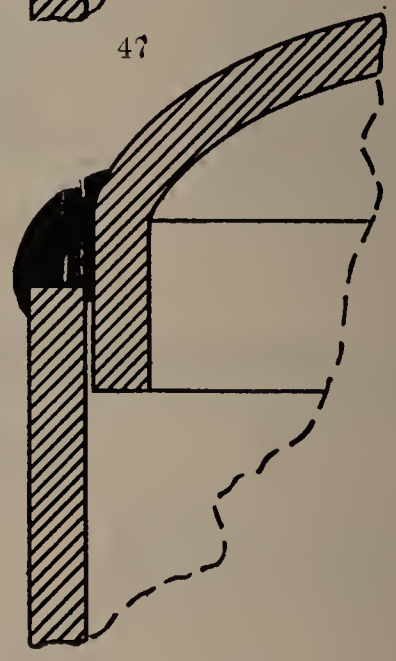

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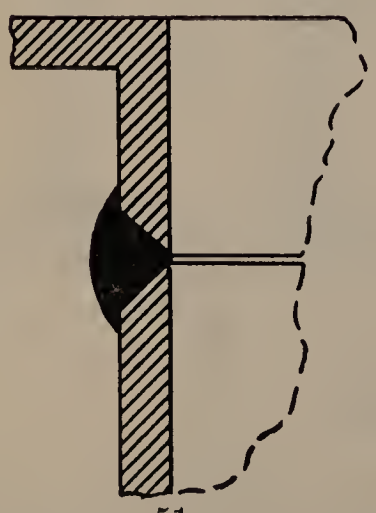

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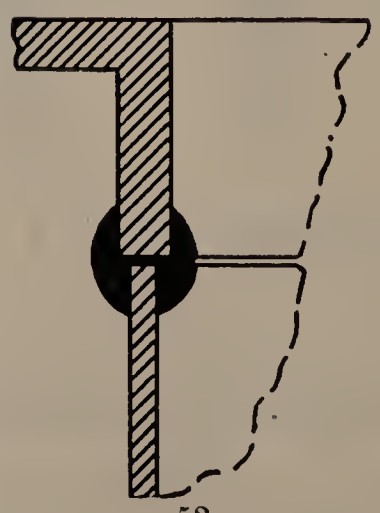

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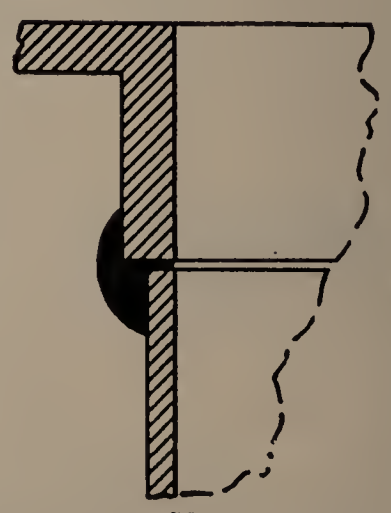

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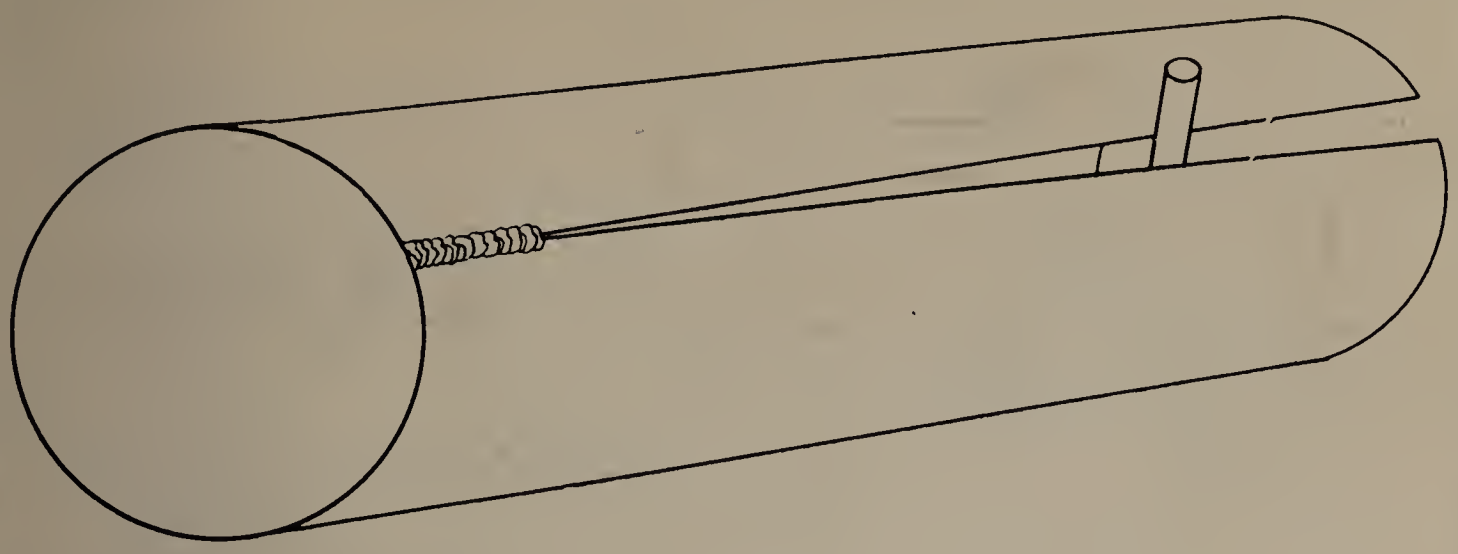

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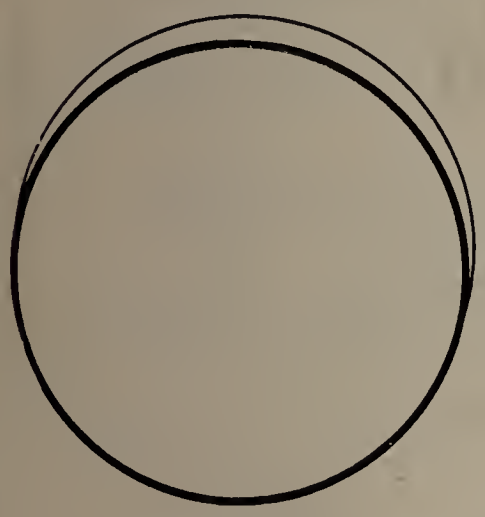

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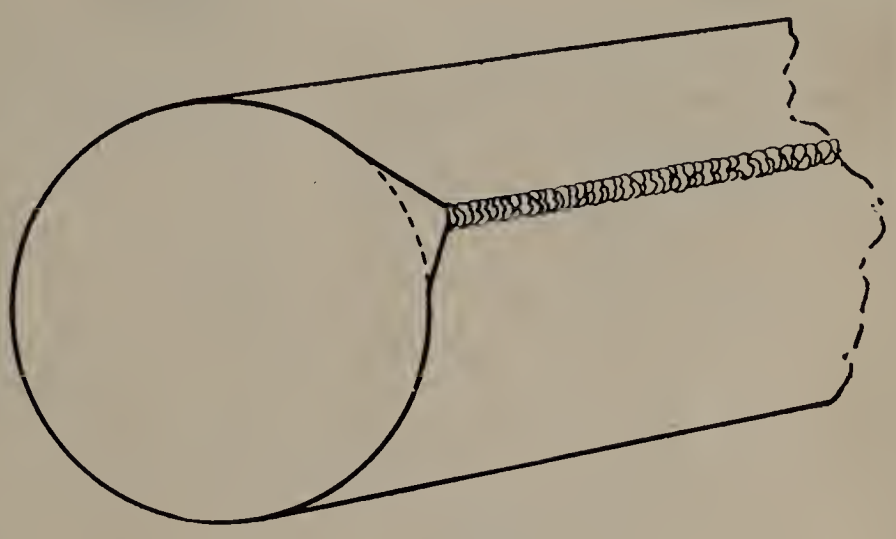

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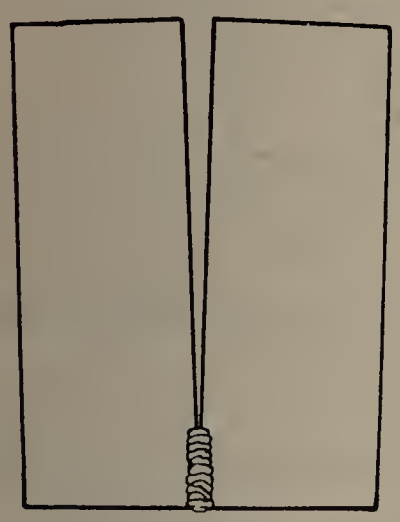

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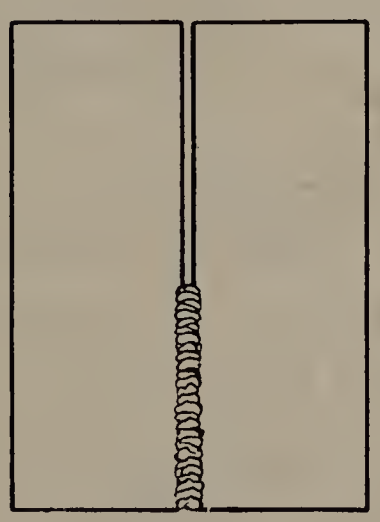

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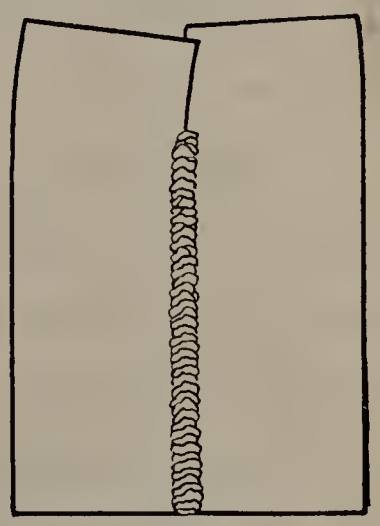

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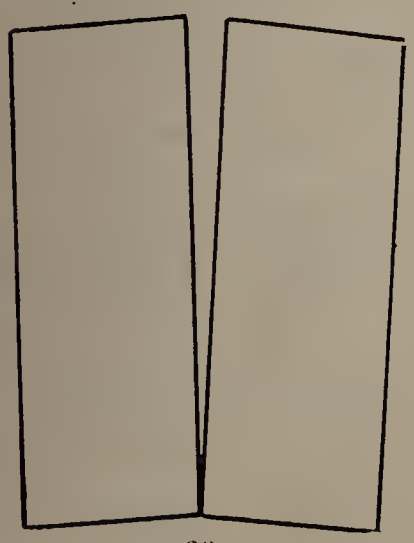

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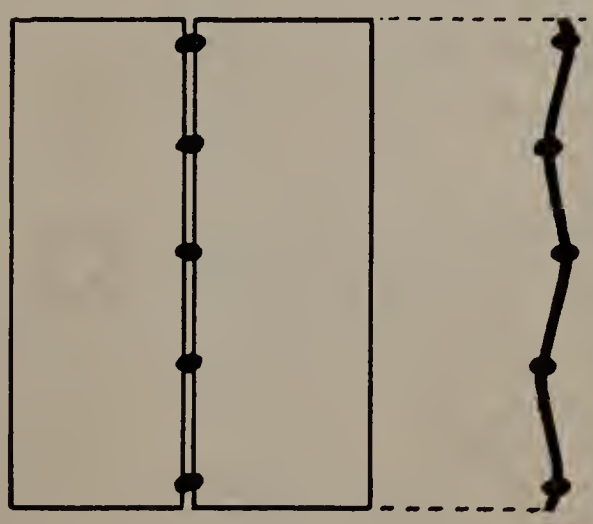

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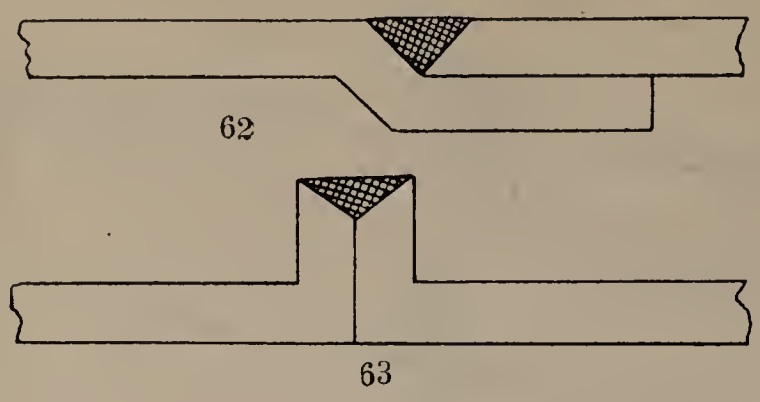
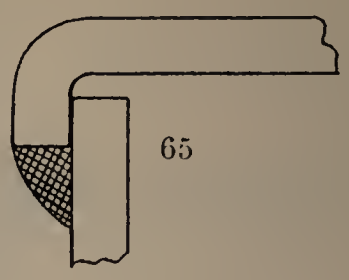
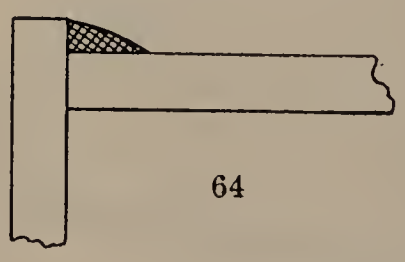
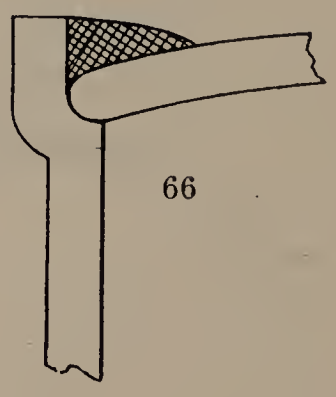
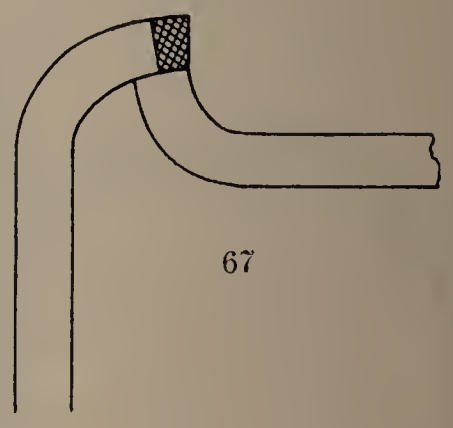










NOMENCLATURE OF TANK JOINTS

A good many of the designs shown on the preceding pages are used in tank construction and several of them have been spoken of as being good designs for welding joints. The following is a list of those which are most popular in tank construction, together with the names ordinarily applied to the joints in practice.

Figure 6, Plain Butt Seam.

Figure 10, Plain Corner Butt Seam.

Figure 11, Single Standard Seam.

Figure 12, Double Standard Seam.

Figure 14 and 15, Square Corner Seam.

Figure 20, Inside Lap.

Figure 43, Plain Seam.

Figure 47, Straight Seam.

Figure 50, Inside Bridge.

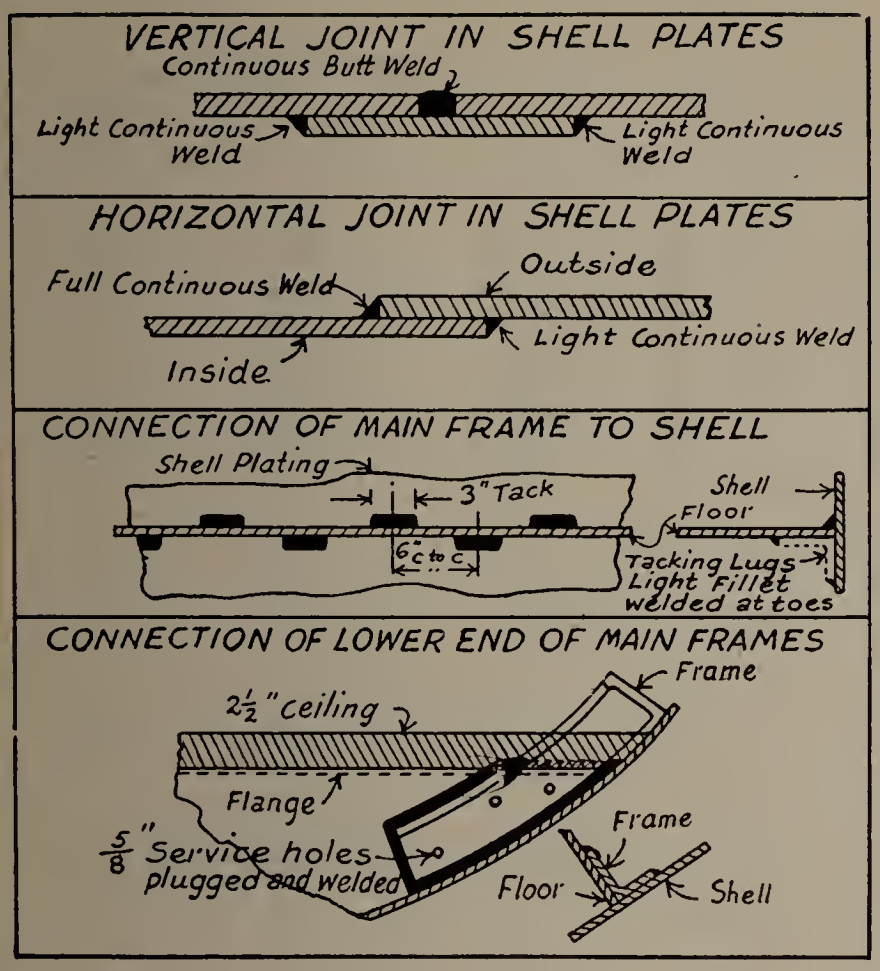
Figure 64, Plain Corner Butt Seam.

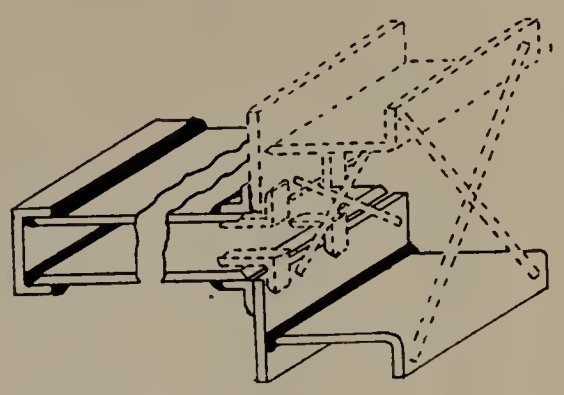
Figure 65, Outside Seam.

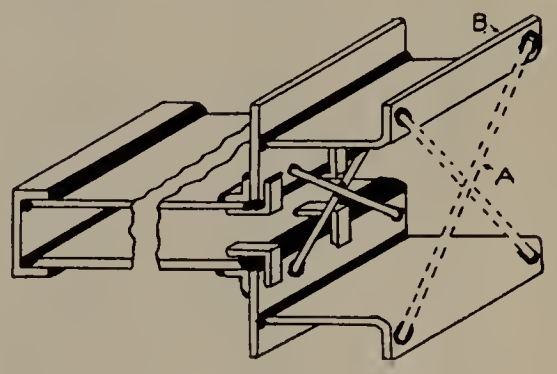
Figure 66, Beaded Seam.

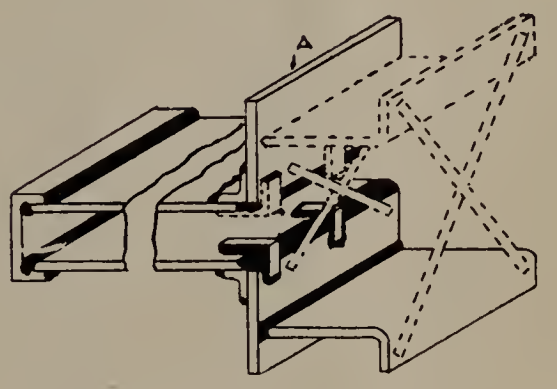
Figure 67, Outside Bridge.

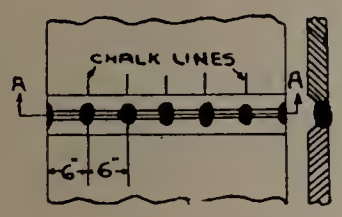
Welded Joints in Plate and Angle Work

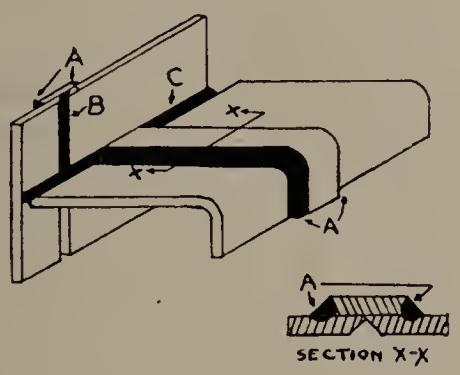


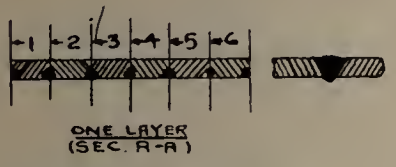


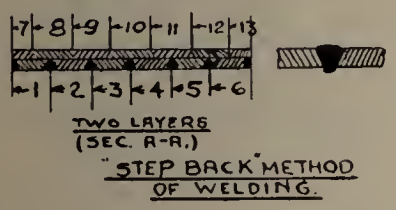


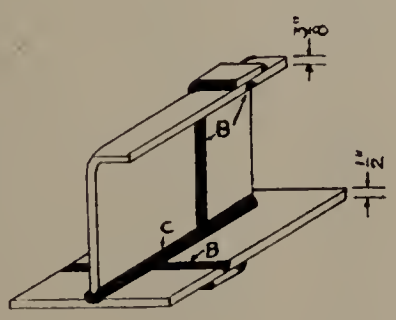


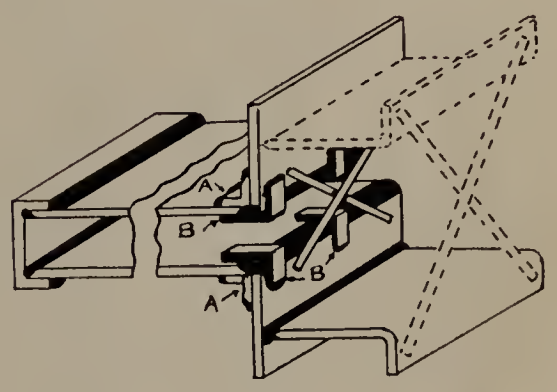


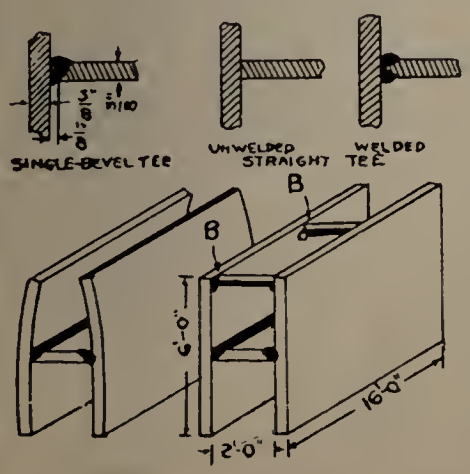


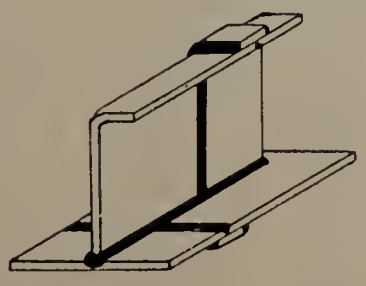


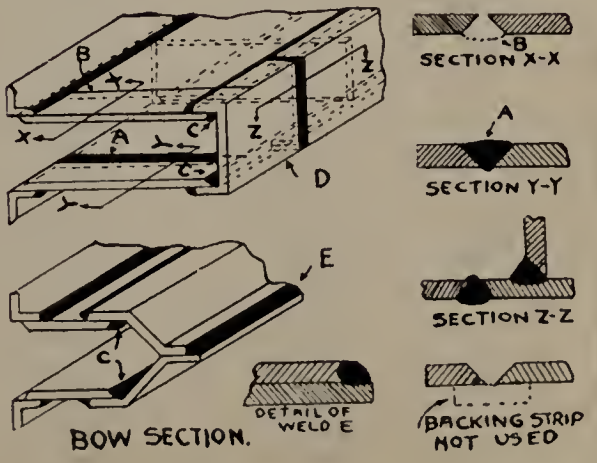












Temperature Tables

Temperature Centigrade=5/9 (Temperature Fahrenheit) —32
Temperature Fahrenheit=32+9/5 (Temperature Centigrade)

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
230	440	575	1067	920	1688	1265	2309
235	455	580	1076	925	1697	1270	2318
240	464	585	1085	930	1706	1275	2327
245	473	590	1094	935	1715	1280	2336
250	482	595	1103	940	1724	1285	2345
255	491	600	1112	945	1733	1290	2354
260	500	605	1121	950	1742	1295	2363
265	509	610	1130	955	1751	1300	2372
270	518	615	1139	960	1760	1305	2381
275	527	620	1148	965	1769	1310	2390
280	536	625	1157	970	1778	1315	2399
285	545	630	1166	975	1787	1320	2408
290	554	635	1175	980	1796	1325	2417
295	563	640	1184	985	1805	1330	2426
300	572	645	1193	990	1814	1335	2435
305	581	650	1202	995	1823	1340	2444
310	590	655	1211	1000	1832	1345	2453
315	599	660	1220	1005	1841	1350	2462
320	608	665	1229	1010	1850	1355	2471
325	617	670	1238	1015	1859	1360	2480
330	626	675	1247	1020	1868	1365	2489
335	635	680	1256	1025	1877	1370	2498
340	644	685	1265	1030	1886	1375	2507
345	653	690	1274	1035	1895	1380	2516
350	662	695	1283	1040	1904	1385	2525
355	671	700	1292	1045	1913	1390	2534
360	680	705	1301	1050	1922	1395	2543
365	689	710	1310	1055	1931	1400	2552
370	698	715	1319	1060	1940	1405	2561
375	707	720	1328	1065	1949	1410	2570
380	716	725	1337	1070	1958	1415	2579
385	725	730	1346	1075	1967	1420	2588
390	734	735	1355	1080	1976	1425	2597
395	743	740	1364	1085	1985	1430	2606
400	752	745	1373	1090	1994	1435	2615
405	761	750	1382	1095	2003	1440	2624
410	770	755	1391	1100	2012	1445	2633
415	779	760	1400	1105	2021	1450	2642
420	788	765	1409	1110	2030	1455	2651
425	797	770	1418	1115	2039	1460	2660
430	806	775	1427	1120	2048	1465	2669
435	815	780	1436	1125	2057	1470	2678
440	824	785	1445	1130	2066	1475	2687
445	833	790	1454	1135	2075	1480	2696
450	842	795	1463	1140	2084	1485	2705
455	851	800	1472	1145	2093	1490	2714
460	860	805	1481	1150	2102	1495	2723
465	869	810	1490	1155	2111	1500	2732
470	878	815	1499	1160	2120	1505	2741
475	887	820	1508	1165	2129	1510	2750
480	896	825	1517	1170	2138	1515	2759
485	905	830	1526	1175	2147	1520	2768
490	914	835	1535	1180	2156	1525	2777
495	923	840	1544	1185	2165	1530	2786
500	932	845	1553	1190	2174	1535	2795
505	941	850	1562	1195	2183	1540	2804
510	950	855	1571	1200	2192	1545	2813
515	959	860	1580	1205	2201	1550	2822
520	968	865	1589	1210	2210	1555	2831
525	977	870	1598	1215	2219		
530	986	875	1607	1220	2228	1560	2840
535	995	880	1616	1225	2237	1565	2849
540	1004	885	1625	1230	2246	1570	2858
545	1013	890	1634	1235	2255	1575	2867
550	1022	895	1643	1240	2264	1580	2876
555	1031	900	1652	1245	2273	1585	2885
560	1040	905	1661	1250	2282	1590	2894
565	1049	910	1670	1255	2291	1595	2903
570	1058	915	1679	1260	2300	1600	2912

Table of Wire Gauges

No.	American Wire Gauge (B. & S.) B. & S. G.		Stub's or Birmingh'm B. W. G.	Washburn & Moen W. & M.	Old English or London O. E. G.	New British Standard E. S. G.
	Millimeters	Decimal of an inch				
0000	11.684	.4600	.454	.393	.454	.400
000	10.404	.4066	.425	.362	.425	.372
00	9.266	.3648	.380	.331	.380	.348
0	8.252	.3249	.340	.307	.340	.324
1	7.341	.2893	.300	.283	.300	.300
2	6.553	.2576	.284	.263	.284	.276
3	5.826	.2294	.259	.244	.259	.252
4	5.19	.2043	.238	.225	.238	.232
5	4.619	.1819	.220	.207	.220	.212
6	4.115	.1620	.203	.192	.203	.192
7	3.665	.1443	.180	.177	.180	.176
8	3.264	.1285	.165	.162	.165	.160
9	2.906	.1144	.148	.148	.148	.144
10	2.588	.1019	.134	.135	.134	.128
11	2.304	.0907	.120	.120	.120	.116
12	2.052	.0808	.109	.105	.109	.104
13	1.83	.0720	.095	.092	.095	.092
14	1.628	.0641	.083	.080	.083	.080
15	1.45	.0571	.072	.072	.072	.072
16	1.29	.0508	.065	.063	.065	,.064
17	1.149	.0453	.058	.054	.058	.056
18	1.0236	.0403	.049	.047	.049	.048
19	.9115	.0359	.042	.041	.040	.040
20	.81	.0320	.035	.035	.035	.036
21	.7239	.0285	.032	.032	.0315	.032
22	.6434	.0254	.028	.028	.0295	.028
23	.574	.0226	.025	.025	.027	.024
24	.5105	.0201	.022	.023	.025	.022
25	.4547	.0179	.020	.020	.023	.020
26	.4039	.0159	.018	.018	.0205	.018
27	.3607	.0142	.016	.017	.0188	.0164
28	.32	.0126	.014	.016	.0165	.0148
29	.287	.0113	.013	.015	.0155	.0136
30	.254	.0100	.012	.014	.0138	.0124
31	.2261	.0089	.010	.0135	.0123	.0116
32	.2032	.0080	.009	.013	.0113	.0108
33	.1803	.0071	.008	.011	.0103	.0100
34	.16	.0063	.007	.01	.0095	.0092
35	.1422	.0056	.005	.0095	.009	.0084
36	.127	.0050	.004	.009	.0075	.0076
37	.113	.0045	.....	.0085	.0065	.0068
38	.1007	.0040	.....	.008	.0058	.0060
39	.0897	.0035	.....	.0075	.005	.0052
40	.0799	.0031	.....	.007	.0045	.0048

Properties of Metals

Elements	Symbol	Density (Specific Gravity)	Weight Per Cubic Foot	Specific Heat	Melting Point	
					Degrees Centigrade	Degrees Fahrenheit
Aluminum	Al	2.6	172.5	0.227	630	1166
Carbon	C	3.51	219.1	0.113	3600	6512
Copper	Cu	8.89	555.6	0.092	1083	1981.4
Gold	Au	19.33	1205.	0.032	1063	1946
Iron	Fe	7.865	490.9	0.115	1530	2786
Lead	Pb	11.37	708.5	0.030	327	621
Nickel	Ni	8.80	555.6	0.109	1452	2645.6
Platinum	Pt	21.45	1336.	0.032	1755	3191
Silver	Ag	10.6	655.5	0.055	960.5	1761
Tin	Sn	7.30	455.7	0.054	231.9	449.5
Zinc	Zn	7.19	443.2	0.093	419	786.2
Bronze (90 Cu 10Sn)	.....	8.78	548	.....	850-1000	1562-1832
Brass (90 Cu 10 Zn)	.....	8.60	540	.....	1020-1030	1868-1886
Brass (70 Cu 30 Zn)	.....	8.44	527	.....	900-940	1652-1724
Cast Pig Iron	.....	7.1	443.2	.....	1100-1250	2012-2282
Open Hearth Steel	.....	7.8	486.9	.....	1350-1530	2462-2786
Wrought Iron Bars	.....	7.8	486.9	.....	1530	2786

Measures of Pressure

Name of Units	Atmospheres	Pounds on Square Inch	Mercury at 32° F.	Inches of Feet of Water at 60° F.	Millimeters of Mercury at 320° F.	Pounds on Square Foot	Kilograms on Square Meter
Atmospheres	1.	14.7	29.922	33.94	760.	2,116.	10,333
Lbs. on sq. in.	.068,03	1.	2.036	2.309	51.7	143.946	702.925
In. mercury at 32° F.	.033,42	.491,3	1.	1.134	25.398	70.7	345.331
Ft. of water at 60° F.	.029,47	.433,2	.881,8	1.	22.399	62.35	304.565
Millimeters of mercury at 32° F.	.001,316	.019,34	.039,37	.044,64	1.	2.784	13.596
Lbs. on sq. ft.	.000,472,6	.006,947	.014,13	.016,03	.359,2	1.	4.883
Kilograms on sq. meter	.000,096,77	.001,423	.002,895	.003,283	.073,55	.204,8	1.

WEIGHT OF WELDING WIRE

Birmingham Wire Gauge	Pounds per 100 feet length Iron	Steel	Brass	Copper
0	30.58	30.92	33.43	35.17
1	25.75	26.04	28.15	29.62
2	21.34	21.57	23.32	24.54
3	18.02	18.22	19.70	20.72
4	15.11	15.28	16.52	17.38
5	12.46	12.59	13.62	14.33
6	11.45	11.57	12.51	13.16
7	9.25	9.35	10.11	10.64
8	7.29	7.37	7.97	8.38
9	6.60	6.68	7.22	7.59
10	4.96	5.02	5.43	5.71
11	4.13	4.18	4.52	4.75
12	3.14	3.18	3.43	3.61
13	2.34	2.36	2.55	2.69
14	1.69	1.71	1.85	1.95
15	1.37	1.39	1.50	1.58
16	1.05	1.06	1.15	1.21

CHEMICAL AND PHYSICAL PROPERTIES OF OXYGEN, HYDROGEN AND ACETYLENE

	Oxygen.	Hydrogen.	Acetylene.
Symbol	0	H	$C_2 H_2$
Density, H=1	16	1	13
Molecular Weight	32	2	26
lbs. per c. foot	.08926	.00559	.07267
c. feet per lb	11.203	178.83	13.456
Grammes per litre	1.4298	.08961	1.190
Litres per gramme	.699	11.16	.840
Weight of Air required to burn 1 unit	—	34.785	13.378
Weight of Oxygen required to burn 1 unit	—	8.00	3.077
Volume of Air required to burn 1 unit	—	2.39	11.93
Volume of Oxygen required to burn 1 unit	—	.500	2.500
Nominal Temperature of Combustion, Air F°	—	4813	6120
Nominal Temperature of Combustion, Air C°	—	2674	3400
Nominal Temperature of Combustion, Oxygen F°	—	12.08	20340
Nominal Temperature of Combustion, Oxygen C°	—	6727	11300
Heat Generated by Combustion of 1 lb., B.T.U	—	62100	21856
Heat Generated by Combustion of 1 c. foot, B.T.U	—	347	1624
Heat Generated by Combustion of 1 gramme, Calories	—	34.5	12.142
Heat Generated by Combustion of 1 Litre, Calories	—	3.091	14.46
Heat Generated by Combustion of 1 Molecule Calories	—	58.3 gas 69 liq. 70.40 sol	315.7
Heat of Formation at 15° per Molecular Calorie	—	—	.58.1
Critical Temperature, Lower Limit C° Absolute	154.2	39	310
Critical Pressure Lower Limit Atmosphere	50.8	20	68
Temperature, Boiling=C°	.181.4	.243	.85
Temperature, Fusion=C°	.211+	—	.81
Density of Liquid, Water=1	1.124	.0714	.451
Specific Heat, Water=1, Constant Pressure	.217	3.410	.373
Specific Heat, Water=1, Constant Volume	.1548	2.4146	—
Molecular Specific Heat, Constant Pressure	6.95	6.82	9.7
Molecular Specific Heat, Constant Volume	4.95	4.8	—
Elementary Specific Heat at High Temperatures	4.95+.00324 (T-1600°)	4.8+.0032 (T-1600°) =14.1 at 4500°	—

CIRCUMFERENCES AND AREAS OF CIRCLES

Ft.	In.	Circumference	Area
1		3.1416	.7854
	1/8	3.5343	.9940
	1/4	3.9270	1.2272
	3/8	4.3197	1.4849
	1/2	4.7124	1.7671
	5/8	5.1051	2.0739
	3/4	5.4978	2.4053
	7/8	5.8905	2.7612
2		6.2832	3.1416
	1/8	6.6759	3.5466
	1/4	7.0686	3.9761
	3/8	7.4613	4.4301
	1/2	7.8540	4.9087
	5/8	8.2467	5.4119
	3/4	8.6394	5.9396
	7/8	9.0321	6.4918
3		9.4248	7.0686
	1/8	9.8175	7.6699
	1/4	10.210	8.2958
	3/8	10.603	8.9462
	1/2	10.996	9.6211
	5/8	11.388	10.321
	3/4	11.781	11.045
	7/8	12.174	11.793

Diameter Ft.	In.	Circumference	Area
4		12.566	12.566
	1/8	12.959	13.364
	1/4	13.352	14.186
	3/8	13.744	15.033
	1/2	14.137	15.904
	5/8	14.530	16.800
	3/4	14.923	17.721
	7/8	15.315	18.665
5		15.708	19.635
	1/8	16.101	20.629
	1/4	16.493	21.648
	3/8	16.886	22.691
	1/2	17.279	23.758
	5/8	17.671	24.850
	3/4	18.064	25.967
	7/8	18.457	27.109
6		18.850	28.274
	1/8	19.242	29.465
	1/4	19.635	30.680
	3/8	20.028	31.919
	1/2	20.420	33.183
	5/8	20.813	34.472
	3/4	21.206	35.785
	7/8	21.598	37.122

Diameter Ft.	In.	Circumference	Area
7		21.991	38.485
	1/8	22.384	39.871
	1/4	22.776	41.282
	3/8	23.169	42.718
	1/2	23.562	44.179
	5/8	23.955	45.664
	3/4	24.347	47.173
	7/8	24.740	48.707
8		25.133	50.265
	1/8	25.525	51.849
	1/4	25.918	53.456
	3/8	26.311	55.088
	1/2	26.704	56.745
	5/8	27.096	58.426
	3/4	27.489	60.132
	7/8	27.882	61.862
9		28.274	63.617
	1/8	28.667	65.397
	1/4	29.060	67.201
	3/8	29.452	69.029
	1/2	29.845	70.882
	5/8	30.238	72.760
	3/4	30.631	74.662
	7/8	31.023	76.589
10		31.416	78.540

United States Standard Gauge for Sheet and Plate

Number of Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch
000	3/8	.375
00	11/32	.3437
0	5/16	.3125
1	9/32	.2812
2	17/64	.2656
3	1/4	.25
4	15/64	.2343
5	7/32	.2187
6	13/64	.2031
7	3/16	.1875
8	11/64	.1718
9	5/32	.1562
10	9/64	.1406
11	1/8	.125
12	7/64	.1093
13	3/32	.0937
14	5/64	.0781
15	9/128	.0703
16	1/16	.0625

Weight of Sheet Iron and Steel

Thickness by Decimal Gauge

Decimal Gauge	Approximate Fractions of an Inch
0.060	1/16
0.065	13/200
0.070	7/100
0.075	3/40
0.080	2/25
0.085	17/200
0.090	9/100
0.095	19/200
0.100	1/10
0.110	11/100
0.125	1/8
0.135	27/200
0.150	3/20
0.165	33/200
0.180	9/50
0.200	1/5
0.220	11/50
0.240	6/25
0.250	1/4

Capacity of Horizontal Storage Tanks

Diameter	Length	Capacity in Gallons
24 in.	5 ft. 0 in.	115
30 in.	5 ft. 0 in.	180
36 in.	5 ft. 0 in.	260
36 in.	6 ft. 0 in.	315
36 in.	7 ft. 0 in.	370
36 in.	8 ft. 0 in.	425
42 in.	5 ft. 0 in.	360
42 in.	6 ft. 0 in.	430
42 in.	8 ft. 0 in.	500

Cubic Feet in a Given Number of Gallons

Gallons	Cubic Feet	Gallons	Cubic Feet
1	.134	6	.802
2	.267	7	.936
3	.401	8	1.069
4	.535	9	1.203
5	.668	10	1.337

CATALOG SECTION

CATALOG SECTION

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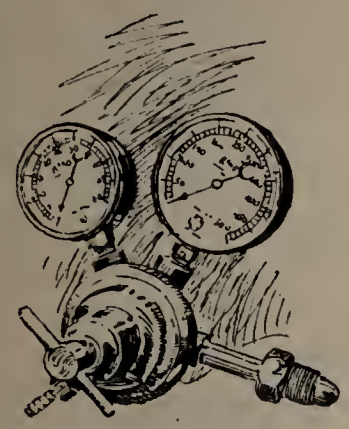
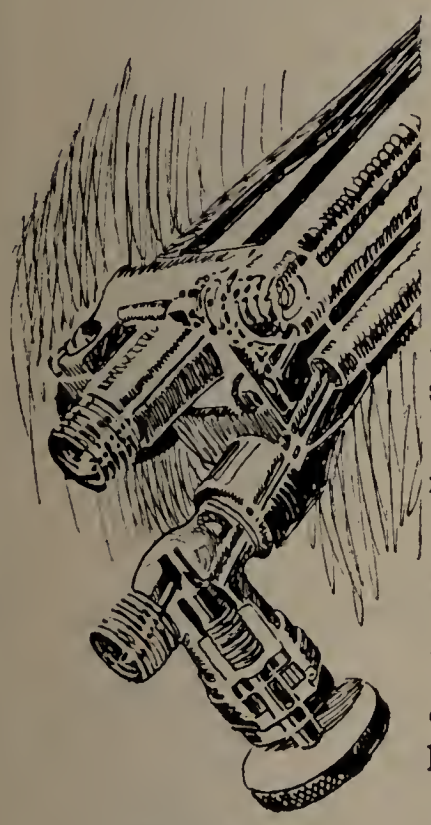


REGO ACETYLENE REGULATOR

OXYGEN for WELDING and CUTTING

ACME Oxygen is 99½% pure CERTIFIED, and will do better welding and cutting. The price is based on consumption, and is the lowest consistent with the quality of the gas and the service we give our customers. The use of Acme Oxygen will assure the highest efficiency in welding and cutting operations.

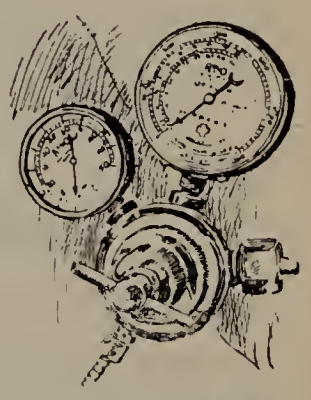
APPARATUS and SUPPLIES for WELDING and CUTTING



REGO CUTTER

For the benefit of users of Acme Oxygen we carry a complete stock of welding and cutting supplies and accessories. Prompt deliveries and reasonable prices make this part of our service popular. Our welding and cutting apparatus is the famous REGO make. A complete description of this apparatus will be found on pages 366 to 370.

Users of Acme Oxygen get the benefit of our engineering service on all problems pertaining to oxy-acetylene welding or cutting.



REGO OXYGEN AND HYDROGEN REGULATOR

ACME OXYGEN COMPANY

Pershing Road and Racine Ave. **Chicago, Ill.**

AIR REDUCTION

Development of "Airco" products for Oxyacetylene Welding and Cutting began with the introduction of the oxyacetylene process to the metal-working industries of the United States. It has been progressively followed by continuous development and expansion of research, production, and distribution facilities.

Today, the largest and most complete line of gases, apparatus and supplies for the oxyacetylene process is comprehended in "Airco Products", while "Airco Service" offers to customers the technical and practical ability and experience developed by direct contact with the progressive needs of the industry and continuous application of the process to new uses and production work.

AIRCO-DAVIS BOURNONV LLE APPARATUS FOR OXYACETYLENE WELDING AND CUTTING

Davis-Bournonville apparatus and manufacturing facilities, together with that company's production, research, sales and service organizations, were merged with Air Reduction Sales Co. in 1922. "Airco-Davis-Bournonville Apparatus" comprises the complete line of Davis-Bournonville oxyacetylene apparatus in addition to the Airco line, including

Welding and Cutting Torches that are the standard of efficiency and economy, with sizes and styles for every requirement;

Oxygen and Acetylene Regulators of recognized superiority, for use with portable tanks or for line service;

Acetylene Pressure Generators of time-proven efficiency, for stationary installation or portable outfits, made in several sizes;

Cabinet Trucks and Hand Trucks for portable outfits;

Welding and Cutting Machines, automatic and semi-automatic, for mechanical welding and cutting on production work, including **Oxygraphs, Radiagraphs, Camographs, Pyrographs,** and **Sheet Metal Welding Machines.**

INDUSTRIAL ENGINEERING SERVICE

The Airco Industrial Engineering Department provides for consulting engineering service on installations of oxyacetylene systems, extension of the process to new applications in production work, co-operation in adapting mechanical welding and cutting methods to customers' products, surveys of plants to establish safety precautions, economies and better efficiency, study of metallurgical and mechanical problems in relation to the oxyacetylene process, and a general service to Airco customers.

ANYTHING AND EVERYTHING FOR

SALES COMPANY

Manufacturer of Airco Oxygen—Airco Acetylene—Airco-Davis-Bournonville Welding and Cutting Apparatus and Supplies, Acetylene Generators, and Specially Designed Machines for Automatic Welding and Cutting—Nitrogen, Argon and other Airco Atmospheric Gas Products.

Controls the Manufacture and Sale of National Carbide

AIRCO DISTRICT OFFICES AND DISTRIBUTING STATIONS

Albany, N. Y.
Atlanta, Ga.
Baltimore, Md.
Bethlehem, Pa.
†*Birmingham, Ala.
2825 North 29th Ave.
†*Boston, Mass.
122 Mt. Vernon St.
Dorchester
Bridgeport, Conn.
Brooklyn, N. Y.
Bronx, N. Y.
†*Buffalo, N. Y.
730 Grant St.
Canton, O.
†*Chicago, Ill.
2236 So. Lumber St.
†*Cleveland, O.
1210 W. 69th St.
Cincinnati, O.
Coatesville, Pa.
Columbus, O.
Defiance, O.
Des Moines, Ia.
†*Detroit, Mich.
7991 Hartwick St.
Duluth, Minn.
East Chicago, Ind.
East St. Louis, Ill.
†*Emeryville, Calif.
Park Ave. & Halleck St.
Erie, Pa.
Fort Wayne, Ind.
Gloucester, N. J.
Grand Rapids, Mich.
Hartford, Conn.
Indianapolis, Ind.
Jersey City, N. J.
Johnstown, Pa.
Joplin, Mo.
Kansas City, Mo.
Lebanon, Pa.
†Los Angeles, Calif.
1940 East Vernon Ave.
Louisville, Ky.
Madison, Ill.
Milwaukee, Wis.
†*Minneapolis, Minn.
327-25th Ave., S. E.
New Haven, Conn.
†*New York, N. Y.
(Metropolitan District)
181 Pacific Ave., Jersey City, N. J.
Brooklyn, N. Y.
Bronx, N. Y.
Norfolk, Va.
*Oklahoma City, Okla.
P. O. Box 1338
Paterson, N. J.
Peoria, Ill.
†*Philadelphia, Pa.
Germantown, and Allegheny Aves.
†*Pittsburgh, Pa.
1116 Ridge Ave.
Portland, Ore.
Portsmouth, Va.
Pottstown, Pa.
†*Richmond, Va.
P. O. Box 1192
Rochester, N. Y.
San Francisco, Calif.
†*Seattle, Wash.
3623 E. Marginal Way
Sharon, Pa.
Springfield, O.
†*St. Louis, Mo.
115 Plum St.
Tacoma, Wash.
Terre Haute, Ind.
Toledo, O.
Tulsa, Okla.
Warren, O.
West Quincy, Mass.
Youngstown, O.

Home Office
342 MADISON AVENUE, NEW YORK, N. Y.

Address communications to nearest Airco District Office.

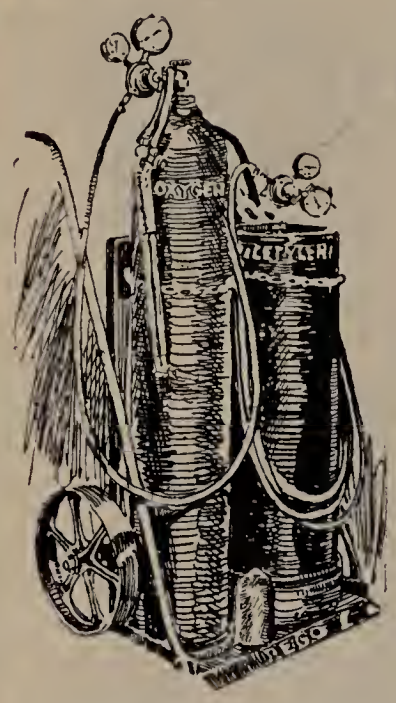
Airco Gas Plants or Warehouses are located in all above-mentioned cities except Los Angeles, which carries Carbide and Apparatus Sales Stock only.

†Airco-Davis-Bournonville Apparatus Sales Stock and Repair Shops, except Oklahoma City, which carries Sales Stock only.

*Airco District Offices.

OXYACETYLENE WELDING & CUTTING

WELDING AND CUTTING APPARATUS



REGO PORTABLE OUTFITS

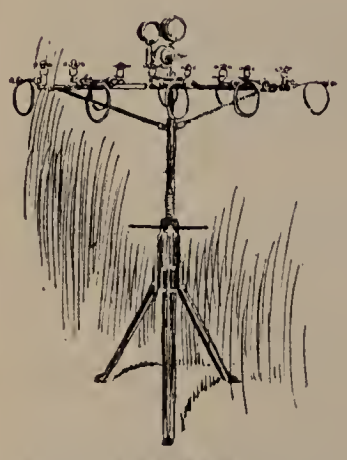
QUALITY has always been the outstanding feature of the Bastian-Blessing Company's products. The REGO line of oxy-acetylene and oxy-hydrogen welding and cutting apparatus is no exception.

THE BASTIAN-BLESSING COMPANY has manufactured apparatus for use with high pressure gases since 1908. As a result of their EXPERIENCE and the ownership of BASIC patents covering the most up-to-the-minute designs and methods—are able to supply the demand for an apparatus which will insure an investment in RESULTS—NOT EXCUSES.

PHENOMENAL growth in sales of REGO in the face of the readjustment period is evidence of its ability to effect true ECONOMY. REGO users are enthusiastic REGO salesmen.

REGO OUTFITS

POSITION of REGO in the trade is unique. Sales are made through distributors who INVEST THEIR MONEY in REGO apparatus. These experienced welding and cutting men have staked their reputations as well as their money on REGO. In a number of cases the distributor is a manufacturer of gas and REGO apparatus has been chosen by these companies to DEVELOP the sale of their products.



REGO TANK MANIFOLDS

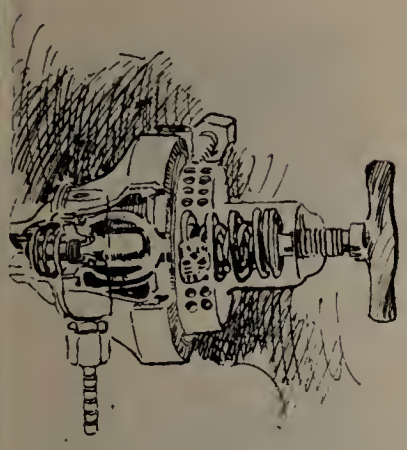
FACTS of this kind speak volumes for the quality and efficiency of REGO. Some idea of the caliber of REGO distributors may be obtained by reference to pages 363, 387, 394, 395, 397, 403, 413 and 420.

REGO line includes special designs for all work and conditions within the scope of the process.

A TRIAL WILL CONVINCE

THE BASTIAN BLESSING COMPANY
WEST AUSTIN AVENUE AT LA SALLE STREET CHICAGO.

WELDING AND CUTTING APPARATUS



REGO REGULATOR DETAILS

SERVICEABLE regulators must deliver a uniform flow of gas, be sensitive at low pressures as well as high pressures, be substantially constructed and be leak and explosion proof.

EXAMINATION of REGO design and construction is convincing of its efficiency in all respects.

REGO regulators permit the gas to flow unobstructed from the tank to the torch. The seat which closes the inlet nozzle is directly connected to the diaphragm and the movement of this seat against the nozzle is controlled by the pressure of the GAS against the diaphragm and not by springs. REGO method of control is POSITIVE. The higher the pressure of gas against the diaphragm the harder the seat is forced against the nozzle.

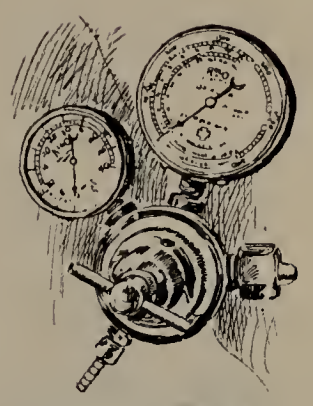
TENSION on the diaphragm of a REGO regulator is secured by two springs—a low pressure spring inside a high pressure spring. This construction gives a wide and ACCURATE range of pressures.

DANGEROUS substances and constructions are all eliminated in the REGO regulator. It is provided with a bonnet or spring housing containing a knife edge and a series of perforations. If for any reason, excess pressure is delivered to the regulator, the diaphragm is forced against the knife-edge thus releasing the gas through the openings in the bonnet without danger of injury to the operator.

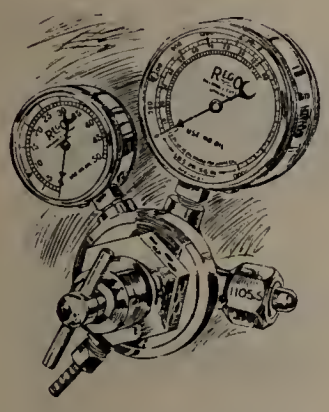
ATTENTION is called to the compact V-shaped type of two gauge REGO regulator which brings the center of gravity of the regulator close to the cylinder valve—THUS relieving strain on the valve and connections.

MORE REGO regulators are in use than any other sold in this country.

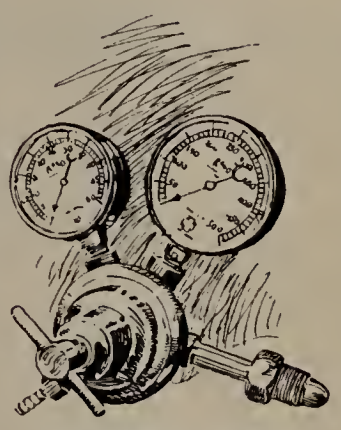
LET US ADVISE YOU ON YOUR REQUIREMENTS



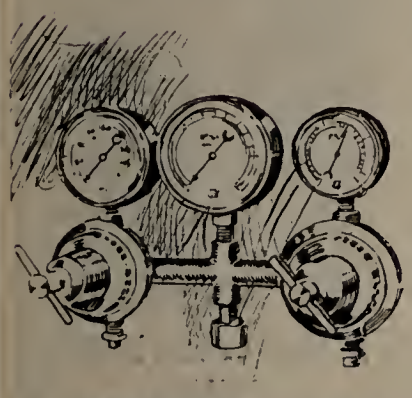
REGO OXYGEN AND HYDROGEN REGULATOR



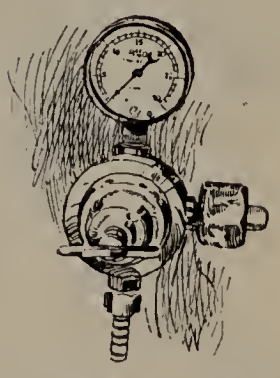
REGO LOOSE DIAPHRAM REGULATOR



REGO ACETYLENE REGULATOR



REGO MANIFOLD REGULATOR



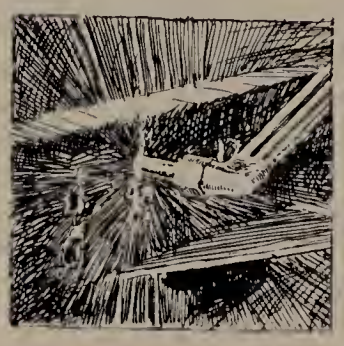
REGO SINGLE GAUGE REGULATOR

THE BASTIAN BLESSING COMPANY
WEST AUSTIN AVENUE AT LA SALLE STREET CHICAGO.

WELDING AND CUTTING APPARATUS

REGO PRINCIPLE of Gas Mixture in torches is a BETTER principle.

IT MATERIALLY reduces—practically eliminates — oxidation, insuring WELDS SOFT AND DUCTILE rather than hard and brittle.



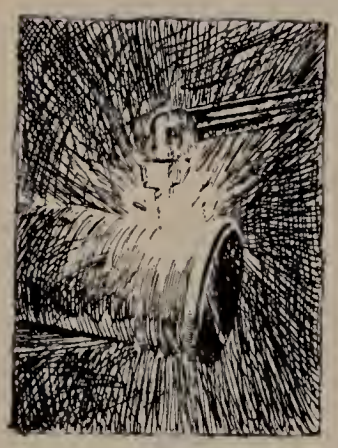
FLASHBACK is done away with—absolutely—under no operating condition will REGO flash. Try some of the tests shown on the margin.

LOW PRESSURES—amazingly low—are used for BOTH gases—drawing practically all of the gas out of BOTH cylinders.

OXYGEN BILLS are cut—the REGO torch burns the theoretically correct mixture of equal volumes, unlike older types which consume as much as two volumes of oxygen for each volume of acetylene.

REGO TORCHES are technically designed; not constructed, as are many others, by cut and try methods.

AREAS of the mixing chamber and the ports carrying the gases thereto are so proportioned in relation to the specific weights of the gases and their angle of delivery that the acetylene enters the mixing chamber at a pressure SLIGHTLY GREATER than the oxygen.



REGO CUTTING TESTS

REGO PRINCIPLE is not one of high acetylene pressure, but of low oxygen pressure. The oxygen pressure for a REGO No. 10 tip (somewhat larger than 1/8") is but 7½ pounds. Torches operating on injector or semi-injector principles require from three to five times this pressure for the same size tip.

REGO WELDING FLASH TESTS

"FACTS" describes in detail the difference between injector, semi-injector or positive pressure, equal pressure and the REGO torch principle.

SEND TO US FOR "FACTS"

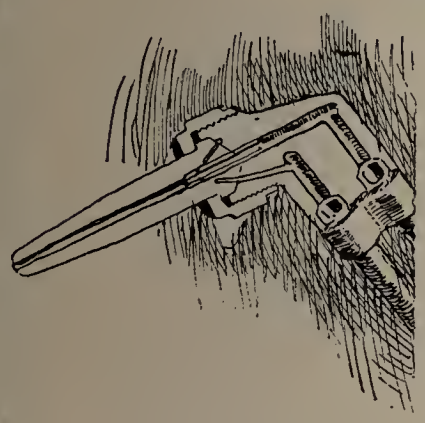
THE BASTIAN BLESSING COMPANY
WEST AUSTIN AVENUE AT LA SALLE STREET CHICAGO.

WELDING AND CUTTING APPARATUS

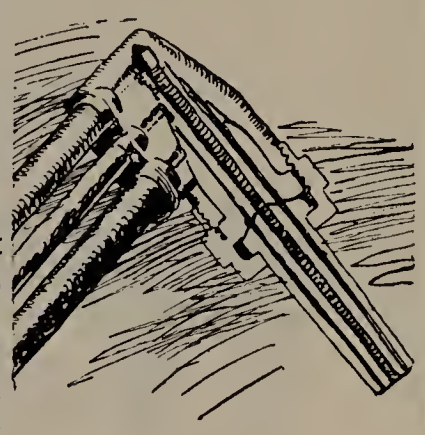
REGO PROPORTIONING OF GASES

MECHANICAL PERFECTION of REGO apparatus adds to its life and popularity.

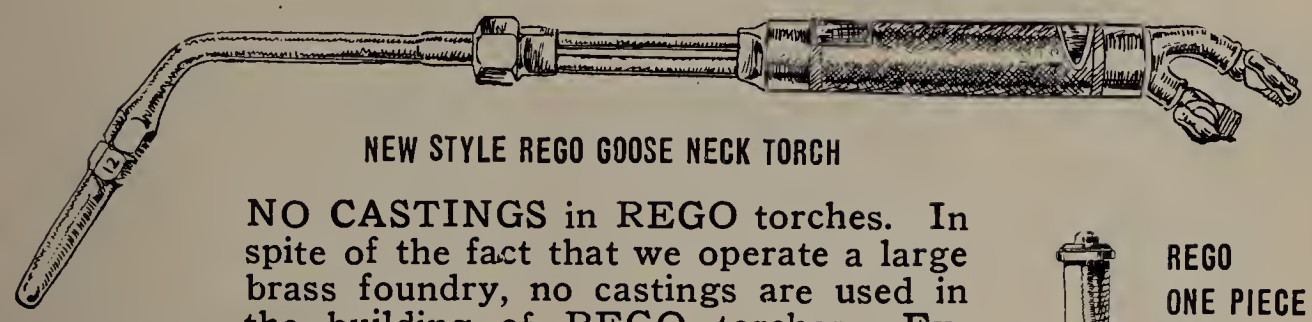
REGO STURDY CONSTRUCTION



TIPS are turned from solid bars of metal (drawn copper for welding—nickel copper for cutting)—no internal or external parts to burn out or get out of adjustment. The metal used in REGO tips, although difficult to machine and drill, is selected because of its incomparable ability to radiate heat away from the end of the tip and thus resist destruction.



TIP SEATS are constructed with broad angle, convex cone. The tips do not bind or stick in the head.



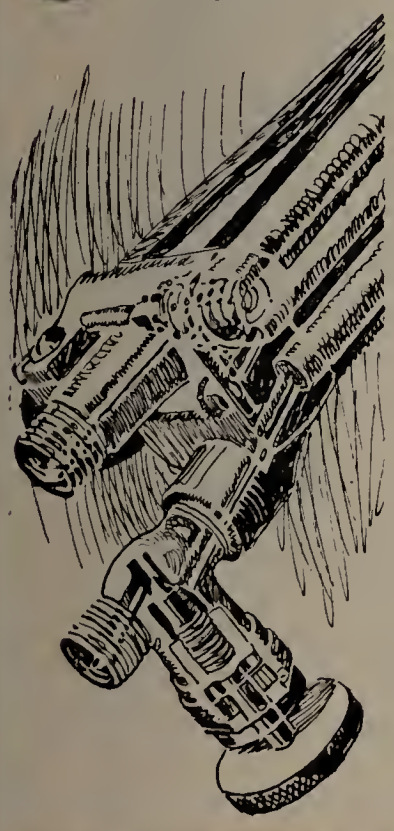
NEW STYLE REGO GOOSE NECK TORCH

REGO ALL COPPER WELDING TIPS

NO CASTINGS in REGO torches. In spite of the fact that we operate a large brass foundry, no castings are used in the building of REGO torches. Extruded brass, made by hydraulically compressing rod brass under 600 tons pressure is the material used for needle valves, valve body and head. With this homogeneous metal there can be no premixture of gases so likely to occur with castings.

REGO ONE PIECE CUTTING TIPS

RIVET CUTTING TIPS



TUBES carrying the gases to the head are heavy seamless brass in girder formation, reinforced with special steel, and silver soldered into the head—strong, NON-LEAKABLE construction.

VALVES on REGO torches are all outside the handle. The long leverage of the high pressure cutting torch valve handle permits the use of a spring sufficiently strong to absolutely close the high pressure valve.

REGO APPARATUS is built to withstand ordinary abuse and any damage is quickly repaired because every part is easily get-at-able.

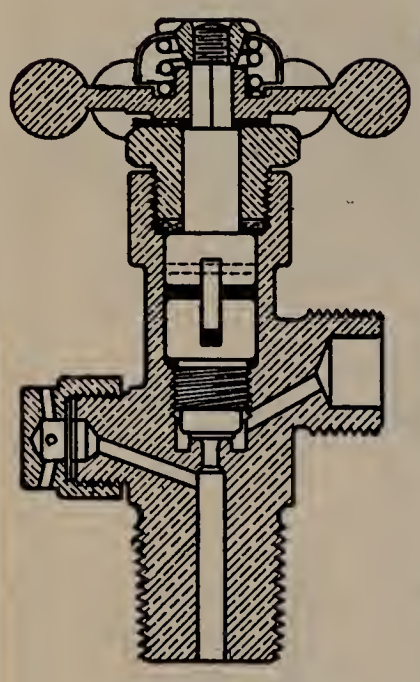
SEND FOR CATALOG

THE BASTIAN BLESSING COMPANY
WEST AUSTIN AVENUE AT LA SALLE STREET CHICAGO.

WELDING AND CUTTING APPARATUS

REGO OXYGEN CYLINDER VALVES

New Style No. 962 for Oxygen and Hydrogen



REGO NO. 962 VALVE

REGO No. 962 Oxygen and Hydrogen valve is the latest development in economical and practical high pressure valve construction. The body is of extra heavy construction. The seating areas are materially larger than in valves of previous construction.

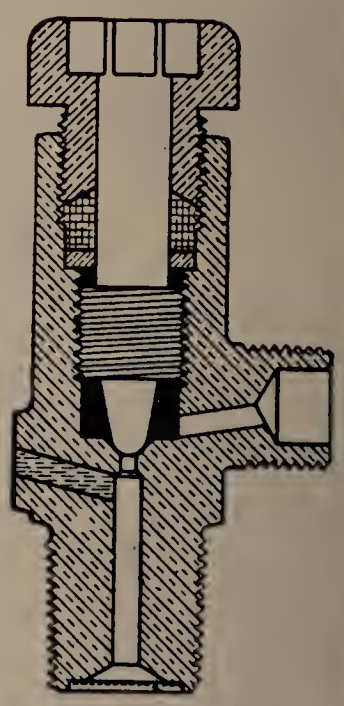
The REGO valve parts are so proportioned that there is absolutely no chance of breaking the interior parts.

The valve seat is made between a flat special soft metal disc, 5/16 inch in diameter and a highly polished and accurately finished brass ring in the valve body. This construction is vastly superior to a conical seat made between two hard metals. Dirt, chips, flakes of metal cannot damage the brass seat in the valve body. Foreign substances are either blown thru the valve or are imbedded in the soft, easily renewed soft metal.

REGO NO. 733 ACETYLENE VALVE

REGO No. 733 acetylene cylinder valve bodies are of the same material and substantial construction as the REGO Oxygen valves.

REGO cylinder valves are standard with a large number of independent oxygen, hydrogen and acetylene manufacturers. Send for prices and names of satisfied users.



REGO NO. 733 VALVE

We also manufacture a complete line of plant equipment, such as charging manifolds, repair tools, purging bottles, etc. Write for catalog 27, part 5.

THE BASTIAN BLESSING COMPANY
WEST AUSTIN AVENUE AT LA SALLE STREET CHICAGO.

Bettendorf Oxygen Service

Available in Iowa and Western Illinois direct
At other points by special arrangements

Oxygen — Hydrogen

Acetylene — Carbide

Apparatus — Supplies

We are prepared to furnish everything for your welding and cutting requirements and give a personal service which insures the best results in the most economical way.

We handle only the most efficient apparatus for welding and cutting, or any use of our gases and we recommend and stand back of all such equipment for continuous service. Let our Service Department solve your welding problems and demonstrate how to get the best results.

The Bettendorf Oxygen-Hydrogen Co.

WORKS AND MAIN OFFICE, BETTENDORF, IOWA

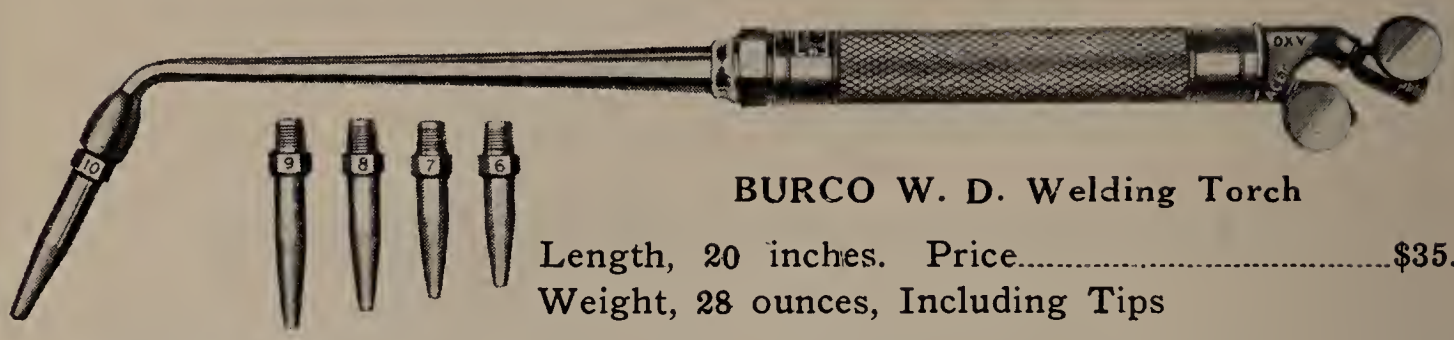
(Manufacturing Suburb of Davenport, Iowa)

NOT the largest but the BEST Service

BURCO TORCHES

for

WELDING AND CUTTING



BURCO W. D. Welding Torch

Length, 20 inches. Price.....$35.00
Weight, 28 ounces, Including Tips

This torch is light but sturdy. It combines perfect balance with long life.

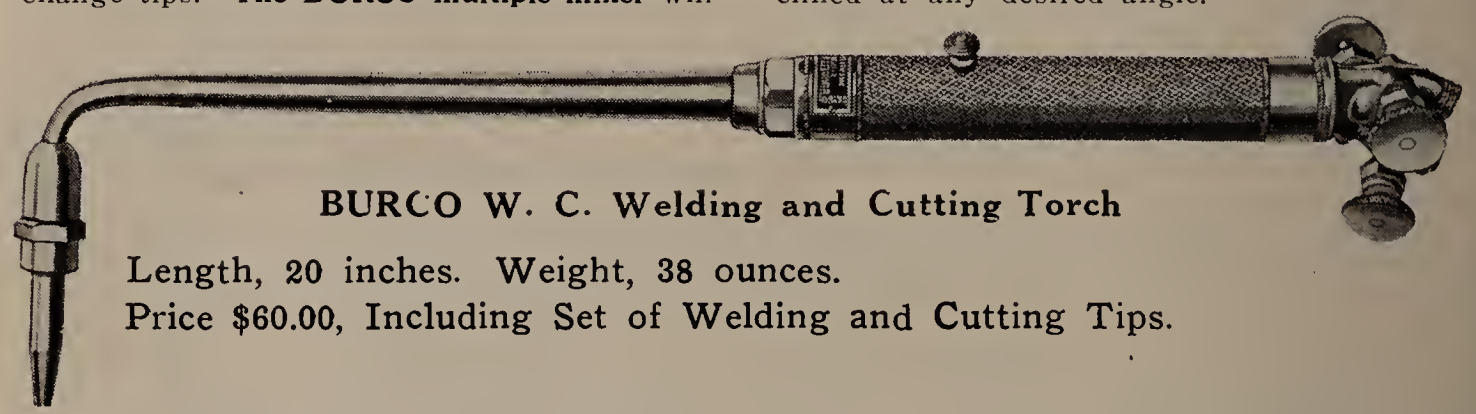
The **BURCO Multiple Mixer** is located at the front end of the handle and mixes the gases **eleven distinct times,** producing the most perfect combination of gases obtainable.

Thorough mixing of gases protects the user against flashbacks and against gas wastage.

You do not have to change mixers when you change tips. **The BURCO multiple mixer** will function with a complete range of tip sizes from No. 1 to No. 20.

BURCO Torches are designed on even pressure principle. Equal volumes of gases are consumed, thus producing a mild neutral flame which makes the metal flow and settle quietly.

BURCO Torches can be furnished with extensions of any length, and with heads inclined at any desired angle.



BURCO W. C. Welding and Cutting Torch

Length, 20 inches. Weight, 38 ounces.
Price $60.00, Including Set of Welding and Cutting Tips.

Welding and cutting are really combined in this torch, and there is no loss of efficiency to either process.

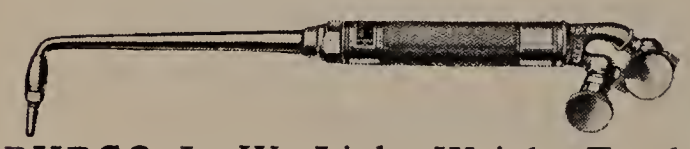
The flame used for welding and cutting is supplied with perfectly mixed gases through the **BURCO** principle of torch construction.

Note the one-piece construction of the cutting torch. This eliminates leaky joints in tubes running from the handle to the head. (Leaky joints mean gas wastage.)

No loosening of tubes—long life—lower maintenance cost—these are special **BURCO** features.

To cut with this torch you simply substitute a cutting tip for the welding tip. It is just as easy as changing from a light welding tip to a heavy welding tip. You don't have to change hose connections.

The **BURCO** W. C. is an ideal torch for the busy shop. It pays for itself by saving gas and time.

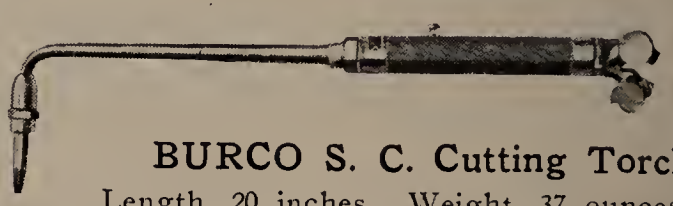


BURCO L. W. Light Weight Torch

Length, 15 inches. Weight, 15 ounces.
Price, including tips.....$25.00

BURCO L. B. Torch

Length, 9 inches. Weight, 8 ounces.
Price $8.50



BURCO S. C. Cutting Torch

Length, 20 inches. Weight, 37 ounces.
Price, including tips.....$50.00

BURCO C. B. Torch

Length, 21 inches. Weight, 10 ounces.
Price $2.50

BURDETT MANUFACTURING CO.

309 St. Johns Ct. **Chicago, Illinois**

MAKERS OF EXPERT WELDING APPARATUS

BURCO REGULATORS

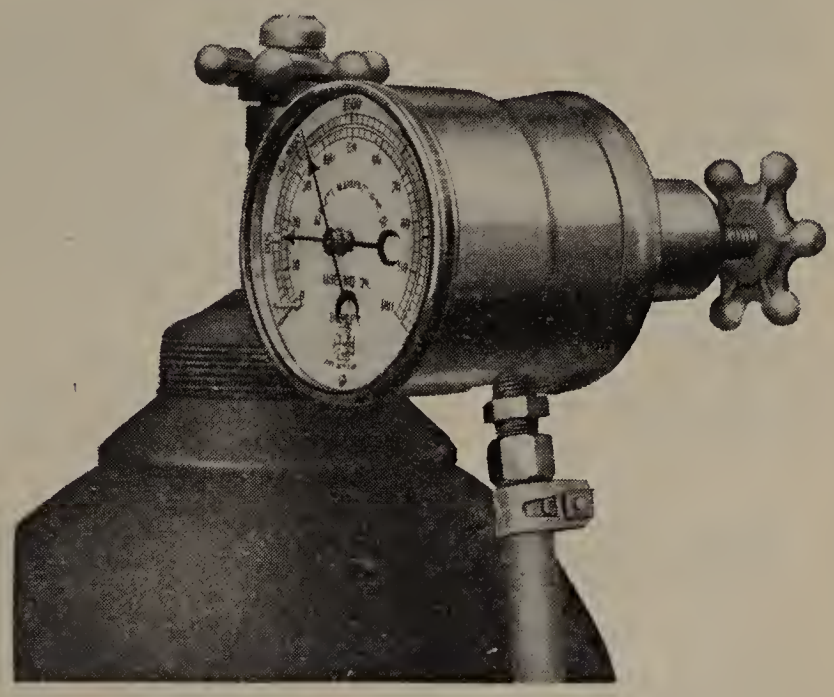
for

WELDING AND CUTTING

The Latest Type of Burco Regulator Construction Sets Record for Reducing Variation

The BURCO Safety STASET (Stay Set) Regulator

Exclusive Features of This Regulator



SENSITIVE — Variation from wide open to closed is 13 oz.

(Average variation of present-day regulators is 30 oz.)

BETTER WELDS—Holds pressure uniform. Operator can give full attention to the weld.

COMPACT—This is the only regulator with two 3 in. gauges built into the regulator body.

FLEXIBLE—It is the only regulator fitted with a flexible expansion spring for low pressures, and a heavy compression spring for high pressures.

ECONOMICAL—It is the only regulator built especially for both welding and cutting, making it unnecessary to buy two regulators.

ACCURATE—This is the most accurate and sturdy regulator ever made in this country or abroad.

LOW FIRST COST—It is the only sensitive laboratory regulator for Welding and Cutting with two 3-in. gauges offered to the welding industry for **$30.00.**

STURDY—All parts enclosed in one strong case. Greatest resistance to wear and shocks.

LOW MAINTENANCE COST—Simplicity of construction. Easily repaired.

Burco Two Gauge Oxygen Regulator

The **BURCO** Regulator is a high and low pressure regulator.

Expansion spring for low pressures, and compression spring for high pressures.

Maximum variation of 1 lb. from open to closed on low pressures, and 2 lbs. on high pressures.

Diaphragm is made of tested and treated diaphragm rubber cloth, and is extremely sensitive and will withstand greater pressures than metal diaphragm.

Regulator seat guide prevents warping and always make a positive gas tight seat.

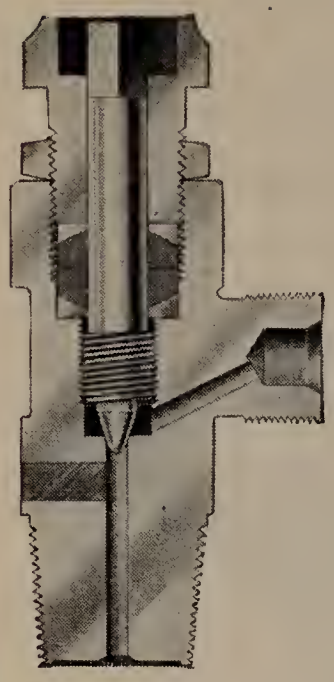
The **BURCO** Regulator can be supplied to work with any compressible gas. Submit your regulator requirements to us, and we will promptly furnish details and prices.

BURDETT MANUFACTURING CO.

309 St. Johns Ct. Chicago, Illinois

MAKERS OF EXPERT WELDING APPARATUS

BURDETT VALVES



Valves That Don't Leak

Valves That Don't Wear Out

Valves That Save You Money

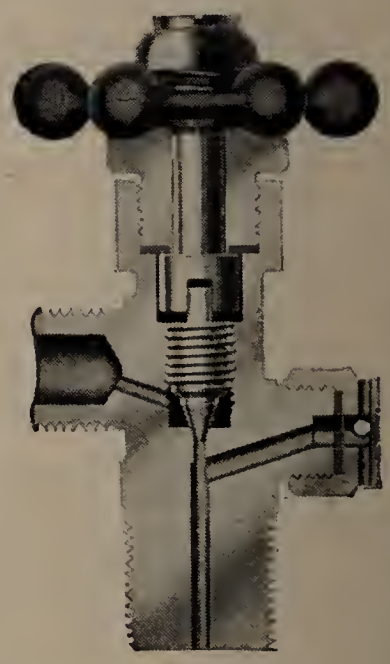
Burdett Acetylene Valve

It can't leak—The Monel Metal swivel seat is **gas-tight** when the valve is closed. The heavy asbestos packing **grows tighter** as the valve is opened.

It can't wear—The body is Tobin Bronze and the **one-piece** stem is Monel Metal, making a **practically indestructible** valve.

You can't go wrong if you buy Burdett Valves for Acetylene Cylinders

The Burdett Standard High Pressure Valve



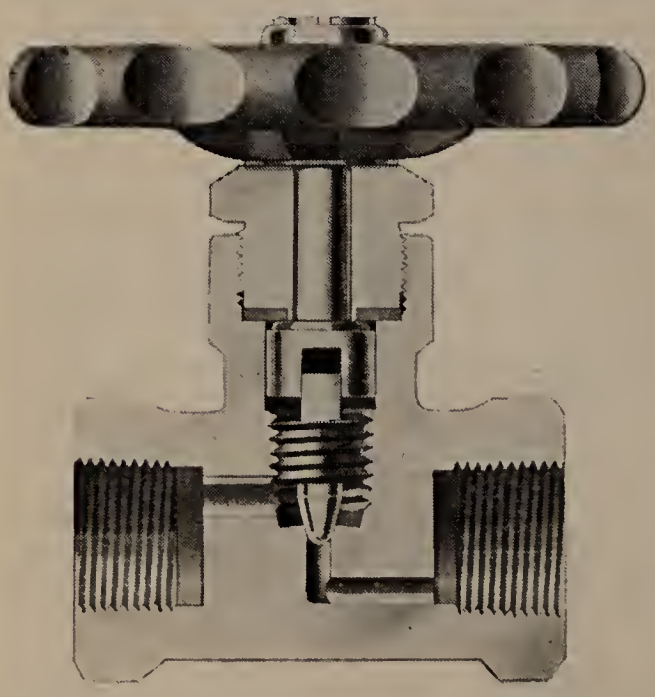
This is a high grade single seat valve **at a popular price.** The swivel mounted tapered seat tip is made of monel metal.

It does not twist nor wear so there are **no new seats to buy** and no "gas leakage" complaints from customers. The plug is connected directly to the stem, making **a stronger valve.**

No broken valve stems to replace.

No twisted valve tongs and spreading of split plugs

No soft seats to replace.



The Burdett Master Valve

The ideal valve **for charging** stand installations or **any** place where you now have globe valves.

It is **lower in initial cost** than most globe valves—and there is **no repacking cost.** It is **made gas-tight** and **stays gas-tight** eliminating costly gas leaks.

The long wearing monel metal seat is **practically indestructible.**

No broken valve stems to replace and cause delays—and **no split plugs.** Easier operation means more economical operation.

All valves are fully guaranteed as to materials and workmanship

BURDETT MANUFACTURING COMPANY

309 St. John's Court **CHICAGO, ILLINOIS**

Carbic

ACETYLENE *from* CAKES

Carbic Low Pressure Portable Generator
Complete weight 200 lbs. (charged)
Listed as Standard by Fire Underwriters Laboratories

100 Lb. Drum Carbic Cakes

The Carbic system of generating acetylene from Carbic cakes, although distinctly in a class by itself, is **not** an experiment. Hundreds of Carbic generators are in daily service in all sections of the country and on all kinds of welding and cutting work.

The use of Carbic permits an ease of handling, an efficiency and safety not otherwise obtainable.

Acetylene from Carbic costs but one-half as much as compressed acetylene and transportation and handling costs are greatly reduced.

A few drums of Carbic insure a large acetylene supply on hand at very little cost.

You should know **all** the advantages of acetylene from Carbic cakes. Let us tell you more of them—a postal will do.

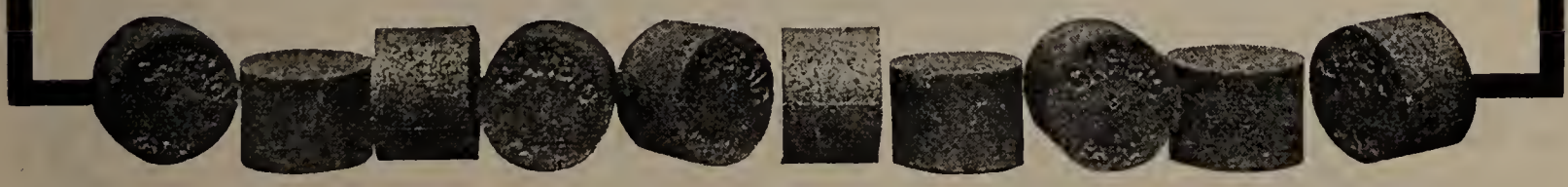
The Carbic line is complete, including generators, torches, regulators, supplies, etc.

CARBIC MANUFACTURING COMPANY

NEW YORK 141 Centre Street
DULUTH General Office and Factory
CHICAGO 565 W. Washington Blvd.
BOSTON 27 School Street
ATLANTA, GA. 169 Haynes St.
CHARLOTTE, N. C. W. 9th St. & So. Ry.
KANSAS CITY, MO. 1411 St. Louis Ave.
EL PASO, TEX. 412 Myrtle Ave.
DENVER, COLO. Hendrie & Bolthoff M. & S. Co.
NEW ORLEANS, LA. Woodward, Wight & Co.
DALLAS, TEXAS Briggs-Weaver Machinery Co.

Warehouses and Representatives in other principal cities.

We are also the manufacturers of the Famous Carbic Portable Lights.



Carbic Cakes save money, time and patience and yield a purer gas.

Scientific Eye Protection

Essentialite Glass

The Scientific Welders' Lens

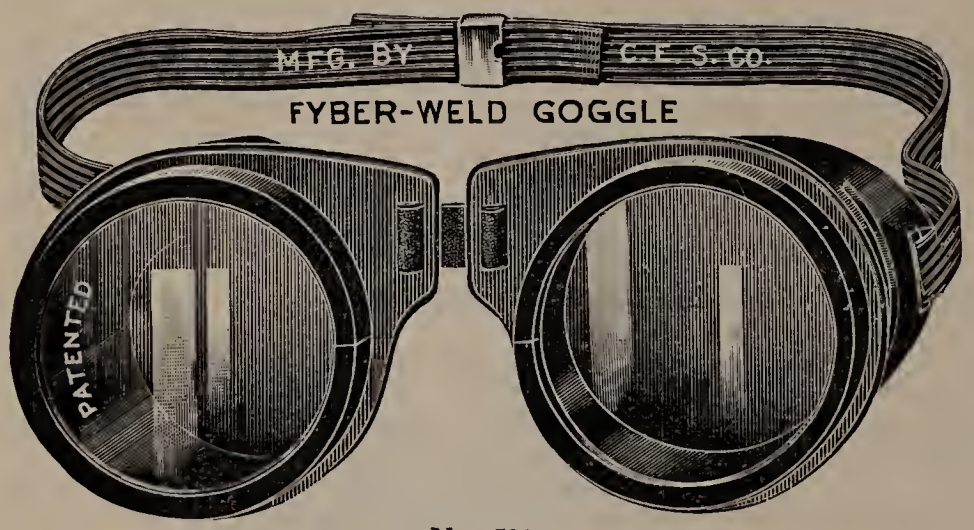
Many welders use colored glass intended to protect their eyes, but in reality this glass often transmits the injurious rays of light and only diffuses the glare and visible rays of light. Too much attention cannot be directed to the selection of scientific lenses.

After years of research, we have finally developed and perfected our "ESSENTIALITE" glass, which affords the welder perfect protection against the harmful rays of the oxy-acetylene flame and the electric arc. The light of the welding arc is largely composed of invisible ultra-violet and infra-red rays. These rays are chemically active and harmful to the vision. Our "ESSENTIALITE" Glass allows the greatest amount possible of visible light with the omission of all the injurious and irritating rays.

The Bureau of Standards, the Navy Department, Prof. Koppius of the University of Chicago, and other authorities have given these lenses the most severe test, and unanimously report that "ESSENTIALITE" glass is scientifically correct. This is your assurance of perfect eye protection.

Practically all of the larger welding concerns and institutions using welding outfits appreciate the necessity of proper eye protection, and therefore are only using the scientific lens. If this proper protection is given to the eye, there is no necessity for anxiety as to the final results to this most delicate organism of the body.

"ESSENTIALITE" glass is made in ten different shades to meet the various protection requirements. For example, shade No. 14 is recommended for oxy-acetylene cutting—shade No. 5 for light oxy-acetylene welding—shade No. 6 for heavy oxy-acetylene welding—shade No. 10 for electric arc welding at 150 amp. —shade No. 12 for electric arc welding up to 250 amp. The Chicago Eye Shield Co. has prepared a complete schedule which will assist you to select the proper lenses for accomplishing the best work in record time, with ample protection.



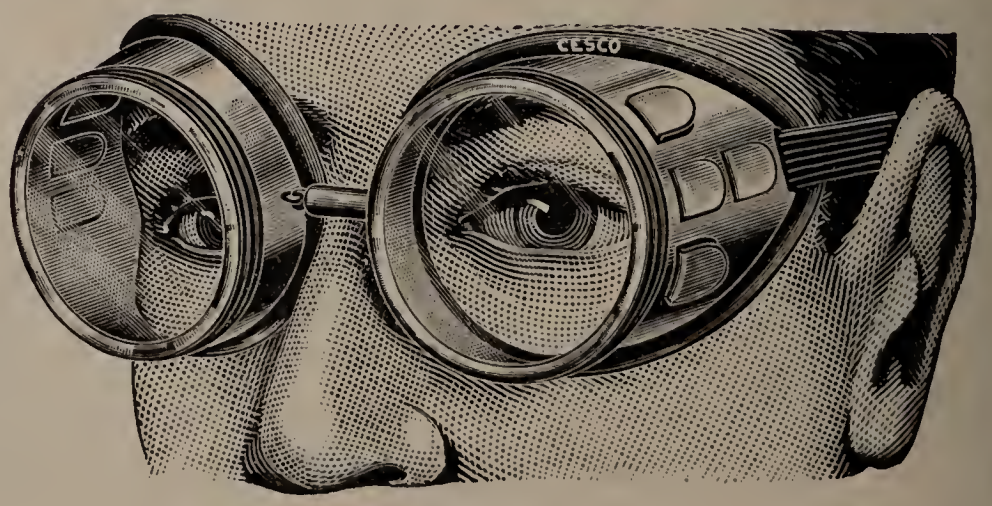
No. 510

"FYBER-WELD" GOGGLES

These goggles are made throughout of special vulcanized fibre which is a non-conductor of heat and electricity. The cups are shaped to fit about the eyes, and are light and strong, making them exceptionally comfortable and serviceable. The ventilation slot is so placed to eliminate all possibility of sparks or light entering. The hinged nose bridge allows the operator to raise the goggles on his forehead when not in use, without discomfort. The patented frames make the interchange of lenses easy. The head band is easily arranged to secure maximum comfort. This is the most **popular welding goggle** on the market.

FITS-WELL GOGGLES

The screw top feature of this goggle renders the interchanging of lenses very convenient, and the special safety flange prevents the lens, if broken, from being driven back into the eye. The rubber covered adjustable nose bridge insures the correct pupilary distance. The ventilation slots in the sides of each cup are adjustable, assuring the welder the greatest amount of comfort. The head band is easily adjustable and also easily removed or replaced.



No. 507R

Chicago Eye Shield Company

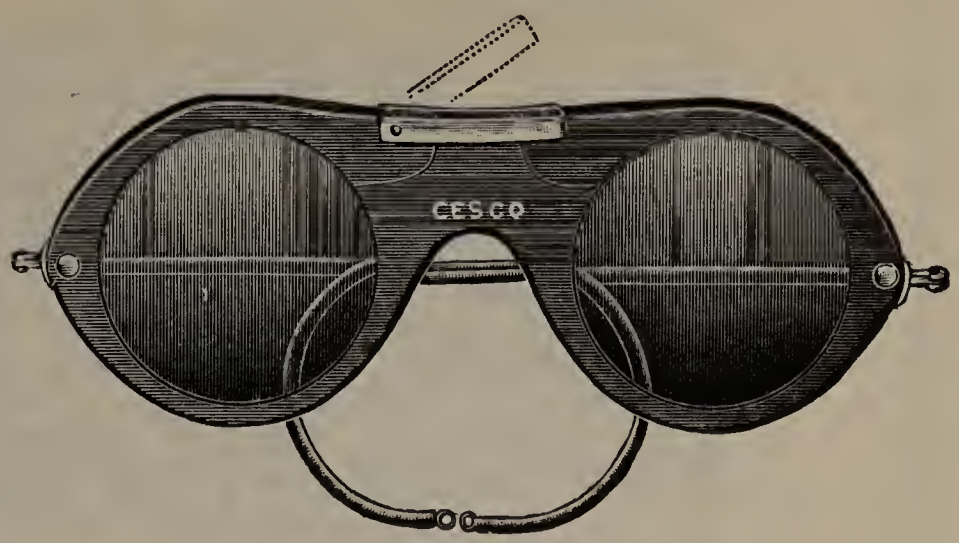
2300 Warren Ave. **Chicago, Ill.**

Scientific Eye Protection

'FYBER-WELD" SPECTACLES

This spectacle is made of fibre which is an absolute non-conductor of heat. It is especially popular with oxy-acetylene cutters who insist upon comfort. It is light and rigid and has all metal parts covered with special heat resisting material. The lens changing device makes it very convenient to change from one lens to another in shops where different types of work require different degrees of eye protection.

Note:—See the discussion of "ESSENTIALITE" glass on opposite page for information regarding special lenses best suited to each type of work.



No. 511

CESCO HELMETS FOR ARC WELDERS

Arrow indicates our improved lens holder with **lift door.** Read details below.

Style "P"

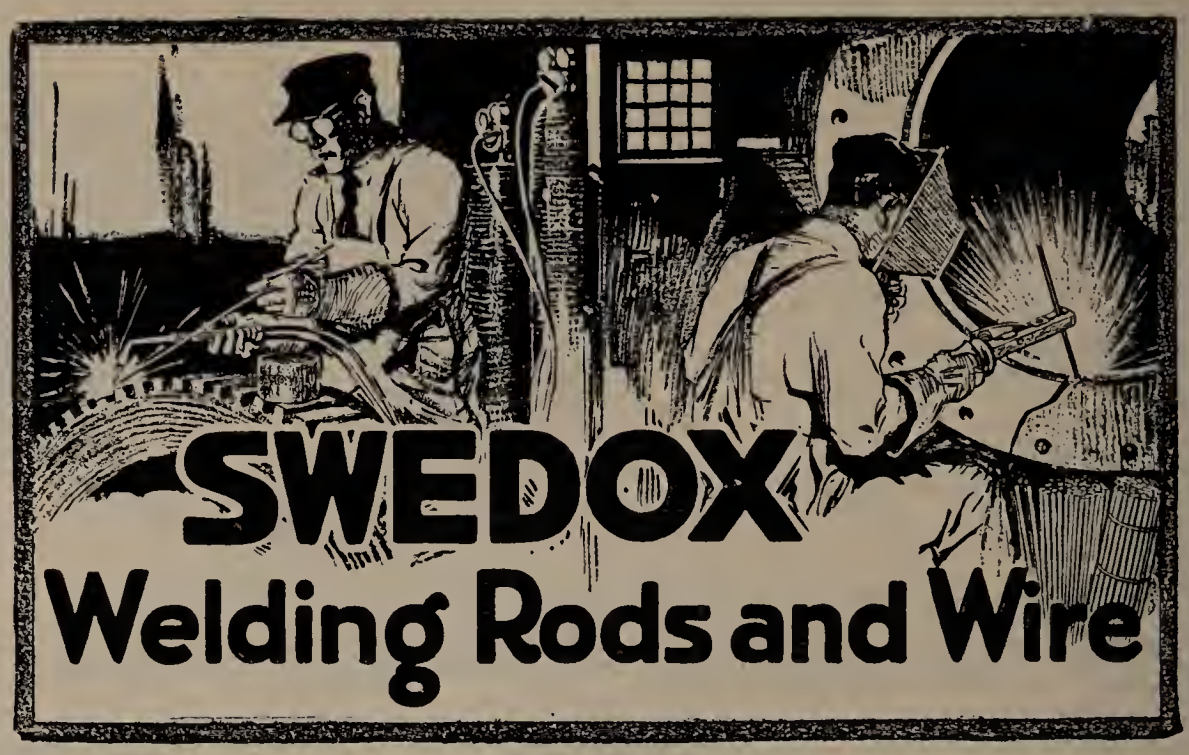
This is a rear view of the style "P" CESCO Arc Welding Helmet, showing the chin rest and forehead rest which hold the helmet absolutely secure, regardless of the position in which the welding is being done. The welder is perfectly protected and has the free use of both hands for his work.

The CESCO Helmet is thoroughly comfortable and practical. It is light in weight, yet durable, being made of fibre with a soft and pliable bib or chest protector. The helmet rests very comfortably on the head of the operator and the weight is evenly distributed. It is also easily adjustable to the head of any wearer. A special feature is our improved lens holder with **lift door,** which contains the welding lenses. This enables the operator to see his work through an inspection window instead of removing the hood, and to change lenses easily and quickly when necessary. Suggestions for the selection of the proper shade of "ESSENTIALITE" glass will be found in the discussion of "ESSENTIALITE" glass on the opposite page.

Consult us freely on all matters pertaining to eye protection.
Our research facilities are always at your disposal.

Chicago Eye Shield Company

2300 Warren Ave. Chicago, Ill.



OUR SWEDOX family covers the following well known brands:

NONOX SWEDOX	NICKOX	SQUARE C CASTOX
LEKTROX SWEDOX	KROMOX	MANGANOX
GAS CARBOX	RAILOX	ALUMINOX
ARC CARBOX	CASTOX	BRONZOX
VANOX	TOBIN BRONZE	BRAZOX

COATED ELECTRODES

As a result of extensive experimental work we have developed a line of coated electrodes, originally for AC machines but which we particularly recommend for DC work. The use of these electrodes increases the efficiency of the weld to a surprising extent, and decreases the labor cost proportionally. Write us for more information about these lines which we list as follows:

STEELKOTE	LEKKOTE	CYLKOTE
NICKOTE	KROMKOTE	RAILKOTE
	MANKOTE	

SWEDOX welding wires and rods can be supplied immediately from stock, conforming in all respects to: *American Welding Society Specifications E No. 1-A; E No. 1-B; E No. 1-C; G No. 1-A; Folios No. 1-E and No. 1-G; and many others.*

PUT YOUR WELDING TROUBLES UP TO US. Let us prescribe the filler best adapted for your requirements. We maintain a research department conducted by experts for the benefit of our customers. This service is FREE OF CHARGE.
FLUXES—CASTOX, BRONZOX and ALUMINOX FLUXES when used with the corresponding filler rod will keep impurities out of the weld and promote thorough fusion.

FREE trial samples of any product will be furnished upon request. A trial of any SWEDOX product will convince you of its superiority. Send for these samples NOW.

Central Steel & Wire Company

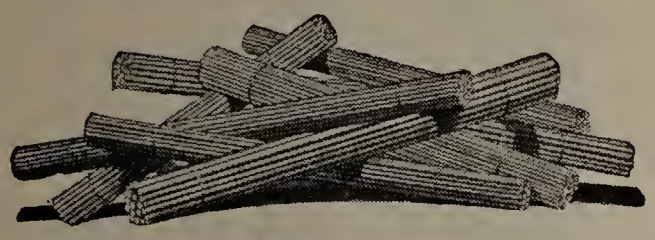
CHICAGO, ILL.
127 N. Peoria Street
Telephone Haymarket 7400

DETROIT, MICH.
Warren & Bellevue Avenues
Telephone Melrose 4032

CRAMP

Parsons' Manganese Bronze Rolled Welding Rods

"The Strongest Bronze Made"



PARSONS' Manganese Bronze Welding Rods extruded and drawn are made from the strongest bronze. Their physical properties average from 75,000 to 80,000 pounds per square inch, tensile strength, in the diameters used for welding. For high fire brazing and oxy-acetylene welding of malleable iron or bronze and brass castings, these scientifically perfected welding rods will aways give a strong, tough weld.

Tests have shown the breaking load of a welded joint in malleable iron made with Parsons' Manganese Bronze to be 43,000 lbs. per square inch, while the breaking load of the nearest competitor was 33,000 lbs. per square inch.

Iron, Aluminum and Steel Welding Rods

In addition to Parsons' Manganese Bronze we keep in stock high-grade Iron, Steel and Aluminum rods which are extensively used with remarkably satisfactory results.

CRAMP'S SOLDERS

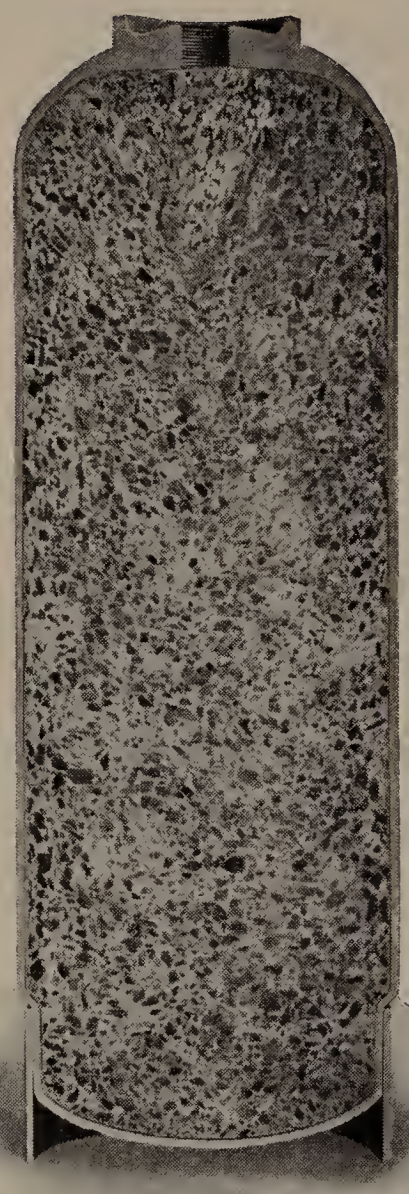
Our Cast Iron and Aluminum Solders are made of virgin metals from special formulas. Cramp's Cast Iron Solder has been found highly satisfactory for repairing cored cylinders, cracked water jackets, etc. We believe that Cramp's Aluminum Solder is the best on the market. A soldered joint properly made with it is superior to a welded joint in point of strength.

We are prepared to make immediate delivery of any of these metals.

THE WILLIAM CRAMP & SONS SHIP & ENGINE BUILDING COMPANY

Philadelphia, Pa.

Acetylene Cylinders



Section Showing Porous Mass

Cylinder With Key and Protecting Cap

"A FEW DETAILS OF OUR CYLINDERS"

Cold drawn, seamless cylinder.

No welds or connections.

Cylinder filled with porous filler, dried and baked.

Impossible to damage filler.

We are the only Manufacturers of this type of cylinder.

"A FEW DETAILS OF OUR PROPOSITION"

CYLINDERS

Our proposition is to loan cylinders on reasonable terms to responsible people. You do not have to pay a deposit or purchase cylinders. You simply pay for acetylene as you need it, we loan the cylinders.

SIZE and CAPACITY

10″x30″—125 cubic feet.
12″x36″—225 cubic feet.
12″x44″—275 cubic feet.

QUALITY

Purest acetylene that can be manufactured. Guaranteed.

SERVICE

That gives our customers acetylene when they need it.

REPUTATION

Ask any welder who has used Commercial Acetylene.

PRICES

Based on customers' requirements.

We would like to tell you more about
COMMERCIAL ACETYLENE

Write to our nearest office

The Commercial Acetylene Supply Co., Inc.

General Offices—80 Broadway, New York City

Main Plant: Bound Brook, New Jersey

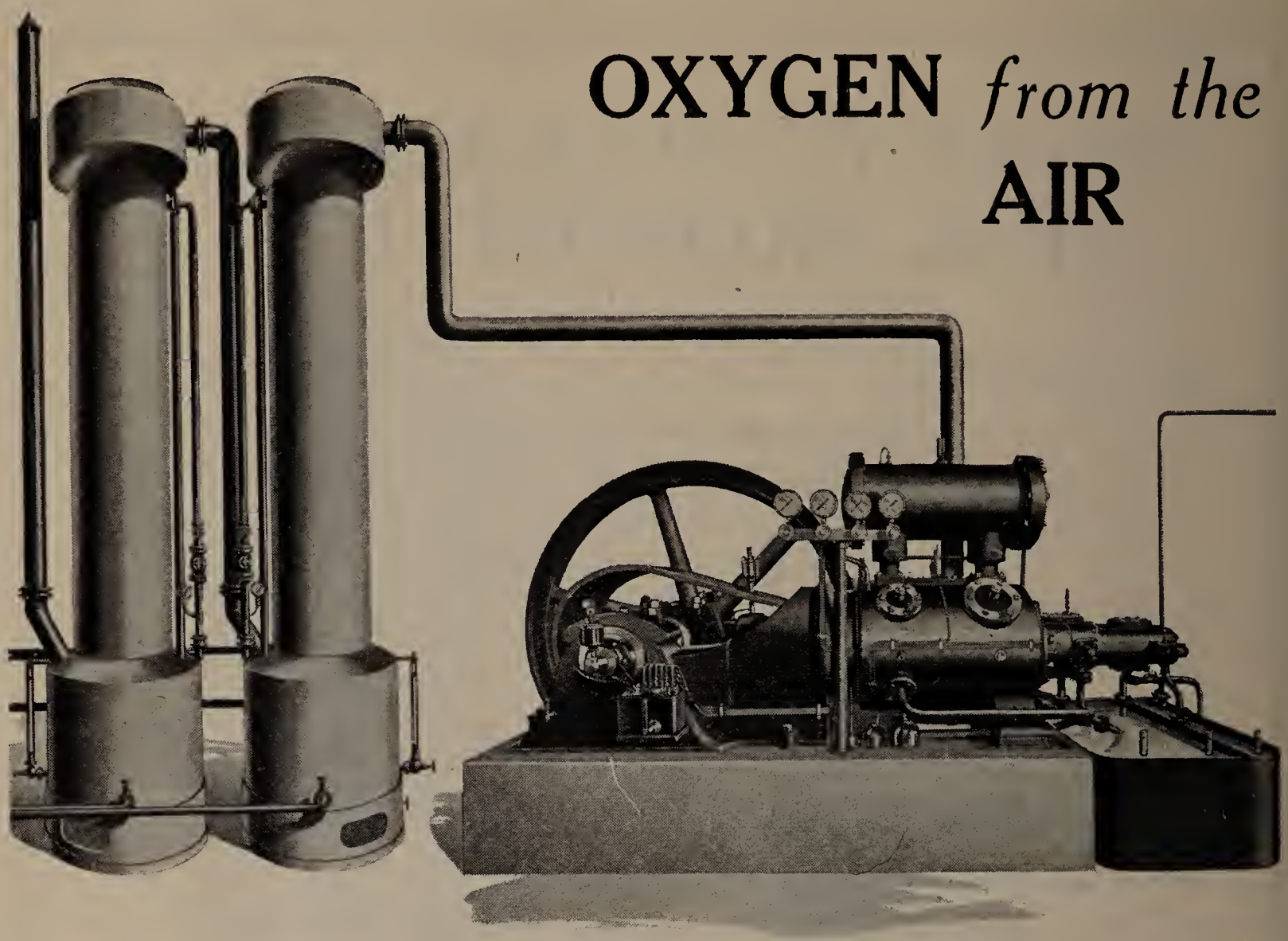
Branch Offices

683 Atlantic Ave., Boston, Mass.
80 E. Jackson Blvd.
553 Monadnock Bldg., San Francisco.
204 Trust Co. of Georgia Bldg., Atlanta, Georgia.

Plants

East Deerfield, Mass.
Blue, Island, Ill.
Los Angeles, Calif.
West Berkeley, Calif.
Atlanta, Georgia.

OXYGEN *from the* AIR



Air Purifying Towers

Four-Stage Air Compressor

OXYGEN of 99% PURITY

produced at the rate of 1000 cubic feet an hour.

Low operating costs, dependability of continuous production and simplicity of construction and operation, are the outstanding features of an Oxeco Liquefaction Plant for the production of gaseous oxygen.

Operating continuously, a monthly production of 600,000 cubic feet of 99% pure oxygen may be readily obtained. However, as a starting period of only thirty-five minutes is required after a twelve-hour shut-down, practically no loss of operating efficiency is encountered if the plant is run only part time, as in a case where maximum demand is less than maximum capacity. One operator on a twelve-hour shift produces economically over 11,000 cu. ft. of 99% pure oxygen.

Simplicity of construction, semi-automatic operation and lack of moving parts (except in air compressor and caustic solution pump) make for long life with low depreciation and render the training of operators an easy matter.

A complete production plant occupies only 700 square feet. No special type of building is required. The flexibility of the plant is illustrated by the fact that the majority of installations utilize formerly unoccupied floor space in existing buildings.

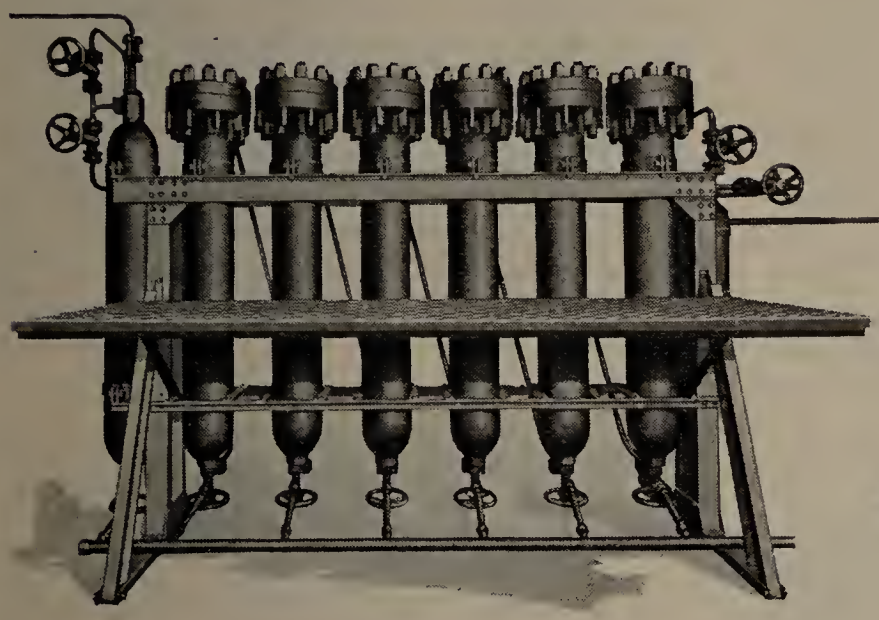
Third and fourth repeat orders prove the entire satisfaction of purchasers. Not only does every plant carry an unqualified American guarantee backed by strong financial responsibility, but attractive terms and options are offered. Complete stocks of spare parts are always available. Engineering inspection and service are parts of every sale.

Whether the installation of a commercial or an industrial plant is being considered, the advantages of deriving oxygen from the air by the liquefaction process should be investigated.

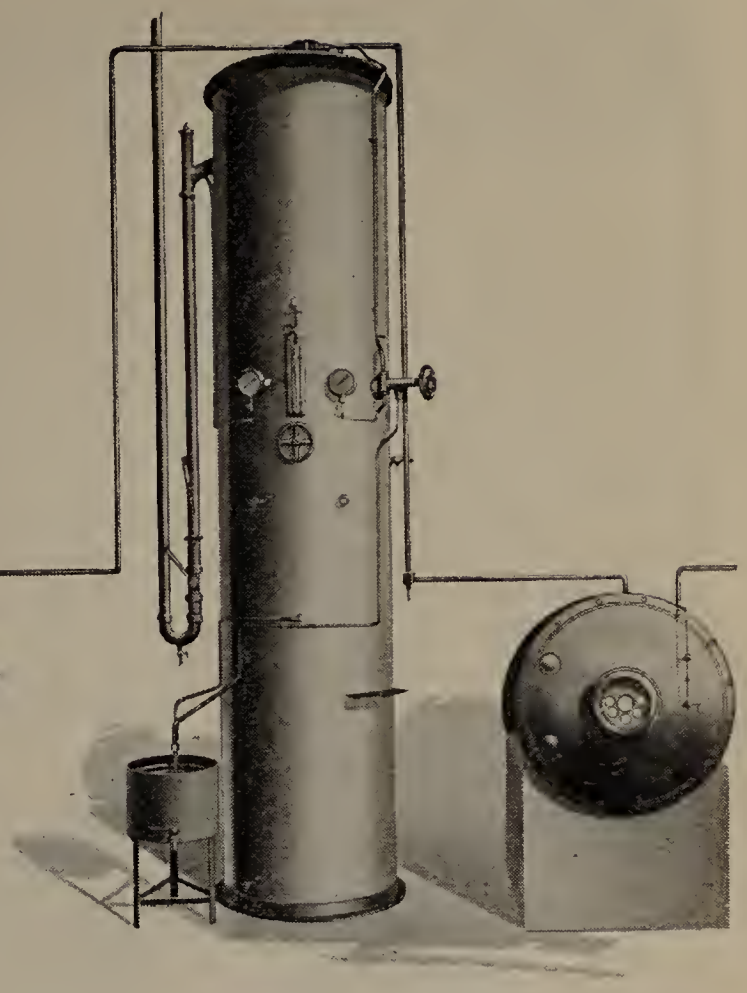
To responsible parties interested we gladly mail **"Oxygen from the Air"**, an exhaustive, elaborately illustrated treatise on the subject.

M. KEITH DUNHAM **110 So. Dearborn St. CHICAGO**

Main Units of an OXECO Liquefaction Plant



Purging Flask and Drying Battery



Liquefaction Column and Gas Meter

THE PRODUCTION PROCESS

Caustic Mixing Tank and Pump

Located to the left of Air Purifying Towers and not shown in the illustration for lack of space. Here the caustic potash solution is mixed and pumped to the upper parts of the towers.

Air Purifying Towers

Air drawn in through the intake pipe by the action of the compressor, enters the first tower at the bottom and in ascending, meets the descending stream of caustic solution sprayed from the upper part of the tower, trickling downward over baffle devices and absorbing the carbon dioxide content of the air. The operation is repeated in the second tower, from whence the purified air enters the

Four-Stage Air Compressor

where is it compressed to a pressure of 55 atmospheres in normal operation. This is accomplished in steps or stages and the heat of compression is removed by adequate water-jacketing and efficient inter-cooling after each stage. An important feature is the use of piston rings instead of stuffing boxes to insure leak-proof cylinders.

Oil Purging Flask and Drying Battery

From the compressor the air passes through an oil purging flask which traps and retains any entrained oil particles and much of the moisture. The residue is periodically blown out through the valve at the bottom of the flask. Thence, the air passes through three cylinders of the Drying Battery, where the last traces of moisture are removed by the hygroscopic action of dry caustic potash. The Drying Battery is in duplicate, permitting continuous operation, no shut-down being necessary when renewing the chemical in either battery of three cylinders.

Liquefaction Column

The column consists of an inner chamber separated from the outer shell by heavy insulation. Compressed air entering at the top passes downward through a series of coils known as the heat interchanger. The function of these coils is to cool the incoming air by exposure to the escaping intensely cold nitrogen. After passing through the heat interchanger, the air is expanded through a simple expansion valve and this expansion further lowers the temperature of the air until it becomes a liquid. The liquid air flows down over a series of baffle plates and by distillation, the nitrogen, due to its lower boiling point of—194° C, is driven off leaving pure liquid oxygen (—182° C) to collect in a reservoir at the base of the column, from whence it passes in gaseous form through the meter into the gasholder.

M. KEITH DUNHAM 110 So. Dearborn St. CHICAGO

"ALTERNARC" CUTTING and WELDING

PORTABILITY DURABILITY FLEXIBILITY

The Alternarc Welder—"Alternarc" welding is based on a principle of arc control, by means of a transformer, fully protected by patents, which maintains constant heat at the arc, and affords precise and positive control of the arc length. It is the only machine automatically holding constant voltage at the arc for a given setting. It is the only commercially successful electric welding system which will operate on alternating current directly without intervention of a cumbersome motor generator. The A. C. apparatus consists of a special transformer, light, simple and compact. With D. C. an equally compact resistor-reactor set is used, embodying the same principles. In general, the "Alternarc" machine will operate from any existing power supply. The only high limit of voltage is that dictated by safety of wiring in the shop or yard. Prices for complete cutting or welding equipments will be quoted upon application. In making inquiries for prices, specify power circuit, and cycles, also details of work to be performed.

Standard Welder

Portability—A complete heavy duty "Alternarc" unit weighs less than 300 lbs. Two men can take the 200 ampere machine anywhere, and it can be connected to the shop or works power supply at any point. No heavy distribution wiring is needed. Each machine operates independently so that change of location may be made as needed. The smaller weight of the transformer as compared to a motor generator set points to a distinct advantage in favor of the "Alternarc." A further point which must not be lost sight of is that the employment of the "Alternarc" involves a smaller investment, and that there is no maintenance, and operating cost is a minimum.

Durability—There is practically no expenditure for maintenance unless the machine should be injured accidentally from outside sources. The "Alternarc" machine has no moving mechanism, except the cooling blower, and this is ball bearing and requires no attention. There is nothing to wear out or need adjustment.

Portability of the "Alternarc"

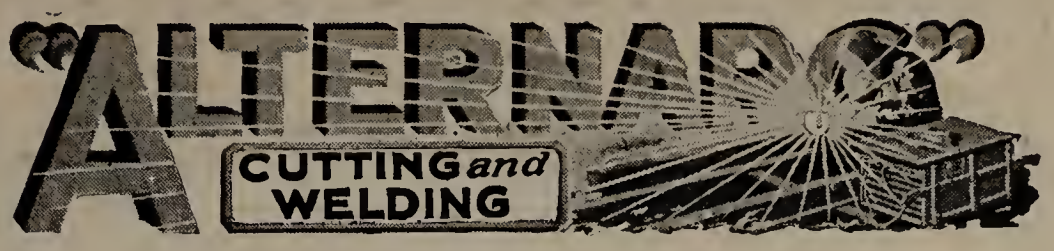
Flexibility—"Alternarc" machines can be operated singly or in multiple, and are provided with variable control which can be adjusted to meet any conditions. Machines use any electrodes and can be operated under any power conditions. Any voltage, frequency or phase of alternating power supply can be used. They are easily moved about from place to place to take care of sporadic production, overtime work, part time work, etc., with equal efficiency and with minimum trouble and cost. "Alternarc" machines will weld steel, cast iron, malleable iron and non-ferrous metals, and can be used for all types of production and repair welding.

Alternating Current Arc Welding—Tests have demonstrated that "Alternarc" welded pieces of steel plate break outside the welds when tested to destruction. Penetration is unusually deep, diffusion unusually thorough and welds correspondingly strong. Speed, too, is an important factor in favor of using this process. It deposits metal as fast as the operator can guide the electrode. The ease of operation of the machine is indicated by the fact that during the rush of war work, girls operated the "Alternarc" apparatus in many places, notably Hog Island, where they were entrusted with considerable production work on ship parts. Here then are the features which distinguish the "Alternarc" method of welding; ease transportation, adaptability to both power supply and work requirements, low initial cost, greater speed, lower power cost, ease of operation, and better results in the weld.

ELECTRIC ARC CUTTING & WELDING CO. 152 Jeliff Ave. Newark, N. J.

Write for the "Alternarc" booklet

PORTABILITY DURABILITY FLEXIBILITY



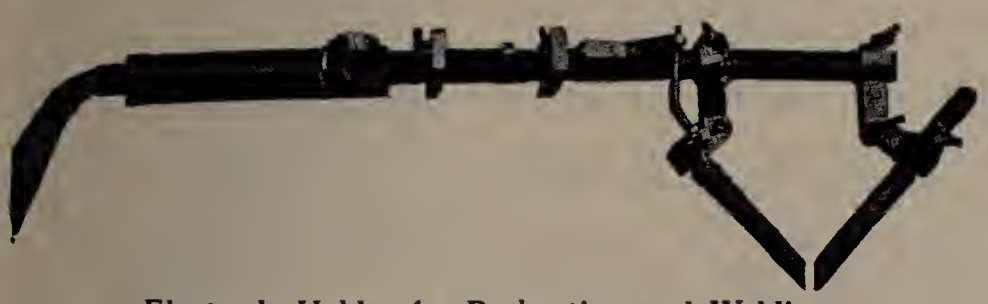
Cutting a Manganese Bronze Propeller

Electric Arc Cutting—Electric cutting is much cheaper than gas and is especially applicable where a finished surface is not necessary, such as cutting up scrap or preparing metals for charging in the furnace, or for emergency cutting or cutting out for welding. Cast iron and non-ferrous metals are especially easy to cut. The arc will cut any metal which will carry the current. The "Alternarc" Cutting Transformer is made in 600 ampere and 1,000 ampere capacity, and provided with a specially designed handle for cutting. For cutting holes, rivets or slots also the arc has unique advantages making it the "BEST" METHOD.

Helmets and Shields—The "Newarc" Helmet is completely insulated and provides for protection to the head of operator from the ultra-violet and infrared rays and sunburning action on the face and neck and from sparks, especially in welding overhead. The correct combination of colored glasses provides the protection to the eyes and permits viewing the fusing action of the metal with the certainty necessary in good welding. When tipped back, the side pieces of the helmet provide protection against flashes from adjacent operators. It is generally worn with a cap, peak backwards, completely protecting the hair. The form fits the chest so that it acts as an efficient protection. We also supply welding gloves and aprons, as shown in the illustration.

Cut shows use of our Helmet or Mask, Observer's shield. Gloves, welding handle and apron. All are treated to Fire Resistant.

Electrode Holder for Metallic Arc Welding



Electrode Holder for Preheating and Welding

Electrodes—Welds for high strength and torsion and bending and welds for high pressure can best be obtained with "Newarc" electrodes. When bare wire is used as an electrode, the metal in flowing through the arc is exposed to the air and may become oxidized and the weld is more liable to be filled with oxides, nitrides and cyanides. With these materials in the weld, only a brittle weld can be obtained. **No chipping is required with our flux-coated wire.**

Electrode Holders—The "Newarc" Electrode Holder consists of an insulated holder made of an alloy which is not affected by the heat of the arc. It provides for the gripping of all types of electrodes at all angles without the tiring necessity for keeping pressure on either grip.

SERVICE FOR WELDERS AND CUTTERS

An Instruction Hand Book, furnished with every "Alternarc" outfit, gives complete instructions for making all types of welds. It is profusely illustrated with line drawings and photos which show how to get the best results. In addition, we put a competent advisory service at the disposal of welders who wish to consult our engineers with reference to special arc welding problems. We operate a free school for welders and are only too glad to answer questions based on our experience.

ELECTRIC ARC CUTTING & WELDING CO. 152 Jeliff Ave Newark, N. J.

Write for the "Alternarc" booklet

Dependable Products
and Dependable Service

Any of the producers listed below can satisfactorily supply your oxygen and hydrogen requirements, also all other necessary supplies for oxy-acetylene and oxy-hydrogen welding and cutting.

Many manufacturers and large trunk line railways have demonstrated their confidence in the ability of these plants to serve, by contracting with them for their entire oxygen supply.

OXYGEN AND HYDROGEN

And all Equipment and Supplies for Oxy-Acetylene and Oxy-Hydrogen Welding and Cutting

Facilities of all plants are at your service, in addition to the plant you contract with.

The Oxygen-Hydrogen Digest, a monthly bulletin which will keep you fully informed regarding progress and improvement in gas welding and cutting, will be sent you free upon request.

Use our free employment service for oxy-acetylene or oxy-hydrogen welders and cutters when you need help or want a job.

GAS PRODUCTS ASSOCIATION
140 South Dearborn Street Chicago, Illinois

Submit Your Welding Problems to Any of These Plants:

CALIFORNIA
California Compressed Gas Co., Los Angeles.
California Compressed Gas Co., Oakland.

COLORADO
Colorado Compressed Gas Co., Denver.

ILLINOIS
Acme Oxygen Co., Chicago.
Burdett Oxygen & Hydrogen Co., Chicago.
Electrox Co., Peoria.
Swift & Co., Chicago.

INDIANA
Indiana Oxygen Co., Indianapolis.
Logansport Oxygen Co., Logansport.

IOWA
Bottendorf Oxygen Hydrogen Co., Bettendorf.

KENTUCKY
Kentucky Oxygen & Hydrogen Co., Louisville.

MANITOBA
Auto-Lite Gas Co., Ltd., Winnipeg.

MICHIGAN
Burdett Oxygen Co., of Detroit, Detroit.
Michigan Ox-Hydric Co., Muskegon.

MINNESOTA
Commercial Gas Co., Minneapolis.

MISSOURI
Kansas City Oxygen Gas Co., Kansas City (two plants in Kansas City).

MONTANA
Mountaineer Welders' Supply Co., Butte.

NEBRASKA
The Balbach Co., Omaha.

NEW YORK
American Oxygen Service Company, New York.

OHIO
Clarke Chemical Co., Wickliffe.
Ohio Electrolytic Oxygen Co., Cincinnati.
Ohio Oxygen Co., Niles.

OKLAHOMA
Burdett Oxygen Co., of Oklahoma, Oklahoma City.
Tulsa Oxy-Hydro Co., Tulsa.

OREGON
Portland Oxygen & Hydrogen Co., Portland.

PENNSYLVANIA
Burdett Oxygen Co., Philadelphia, (plants at Chester and Norristown).
Burdett Oxygen & Hydrogen Co., Pittsburgh.

TENNESSEE
Burdett Oxygen Co., Chattanooga.
Memphis Oxygen Co., Memphis.

TEXAS
Burdett Oxygen Co., of Texas, Forth Worth.
Magnolia Gas Products Co., Houston.

UTAH
Utah Compressed Gas Co., Salt Lake City.

WASHINGTON
Washington Compressed Gas Co., Seattle.

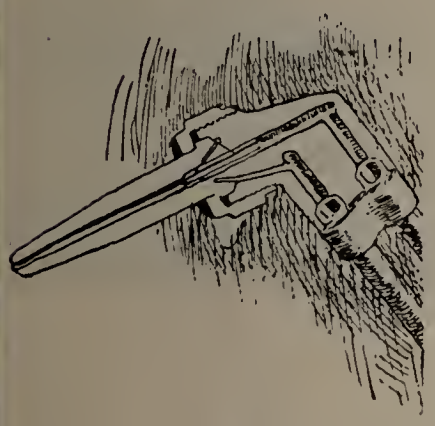
WISCONSIN
Universal Oxygen Co., Sheboygan
Wisconsin Oxygen & Hydrogen Co., Kenosha.

The GAS PRODUCTS CO.

COLUMBUS, OHIO

Cutting and Welding Service

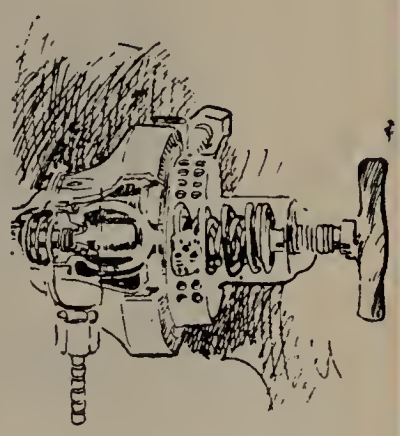
REGO PROPORTIONING OF GASES



"RED HEAD" ACETYLENE

Purified and Compressed into 300 cubic feet cylinders with *"Red Heads"*

Three Acetylene Generating Plants



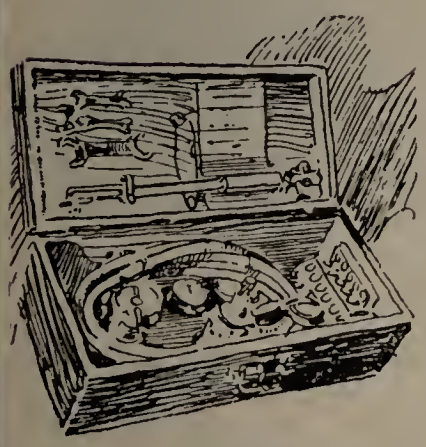
REGO REGULATORS

REGO ALL COPPER WELDING TIPS

"RED HEAD" OXYGEN

Liquid Air Oxygen Compressed into 220 cubic feet cylinders with *"Red Heads"*

Three Oxygen Generating Plants



REGO OUTFITS

Prompt Adequate Service

Distributors of REGO welding and cutting equipment, (see pages 366 to 370) Calcium Carbide, Welding Supplies, Welding Rods.

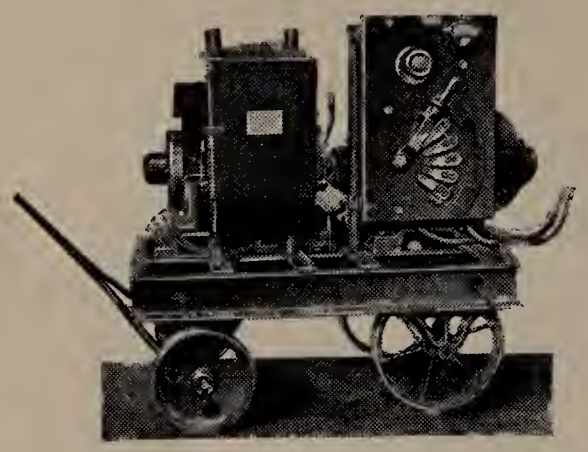
The GAS PRODUCTS CO.

COLUMBUS, OHIO

S. D. WINGER, Vice Pres., & Gen. Mgr.

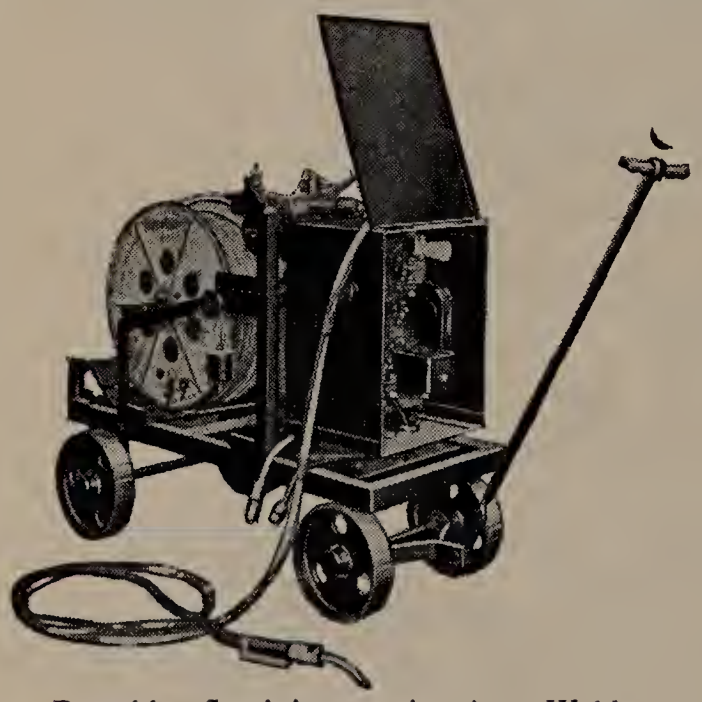
Electric Arc Welding Equipment

G-E electric arc welding equipments are of three types—manual, automatic, and semi-automatic. For general use, both single and multi-operator motor generator sets are available, primarily for metallic electrode welding. Equipments can be also furnished for use with carbon electrodes for cutting. The generators can be driven by any standard form of power. (Bulletin 48932B)



Single Operator Arc Welding Set

G-E Semi-Automatic Welders—This apparatus is for use with the G-E automatic welding equipment to accomplish continuous welding and still permit the operator to direct the arc as required by the conditions of the work. Its field of application is welding seams of irregular contour or large work where the travel mechanism and clamping necessary with the full automatic type would be costly or impracticable. It can be used also for rapidly filling blow holes in castings or



Portable Semi-Automatic Arc Welder

building up worn spots. Its portability gives it a wide range of usefulness. (Bulletin 48932B.)

G-E Automatic Arc Welders—This is a mechanical device to feed automatically a metallic electrode to the work and maintain a constant arc length. It can be operated from any d-c. source of power.

This apparatus is especially applicable for routine, duplicate welding of pipe or tank seams. Attached to machine tools it builds up worn or undercut surfaces of shafts, axles, and plates. It

Welding Tank Seams with Automatic Welder

eliminates the unsteady conditions incident to hand manipulation of the electrode and makes a better weld in 20% to 50% of the time required by hand. (Bulletin 48932B.)

G-E Resistor Arc Welders—The Type AW Resistor Arc Welder is specially designed for the welding of rail bonds, fish plates, etc. It combines light weight and portability with low first cost. It can be operated from the trolley circuit on electric street railway systems or in mines. The 200-275 volt welder weighs 60 lbs.; the 400-650 volt welder weighs 150 lbs. Both have handles conveniently placed to facilitate transportation from joint to joint. (Bulletin 68902)

Resistor Welder for Welding Rail Bonds, Fish Plates, Etc.

Accessories—Electrode holders for both metallic and carbon electrodes, extra flexible cable for attaching to electrode holders, face shields, and head masks may also be supplied on short notice.

General Electric Company Schenectady, New York

GENERAL ELECTRIC

43B-812

GENERAL WELDING & EQUIPMENT CO.

G.W.E.C.

74 BROOKLINE AVENUE, BOSTON, MASS

WELDING AND CUTTING EQUIPMENTS.

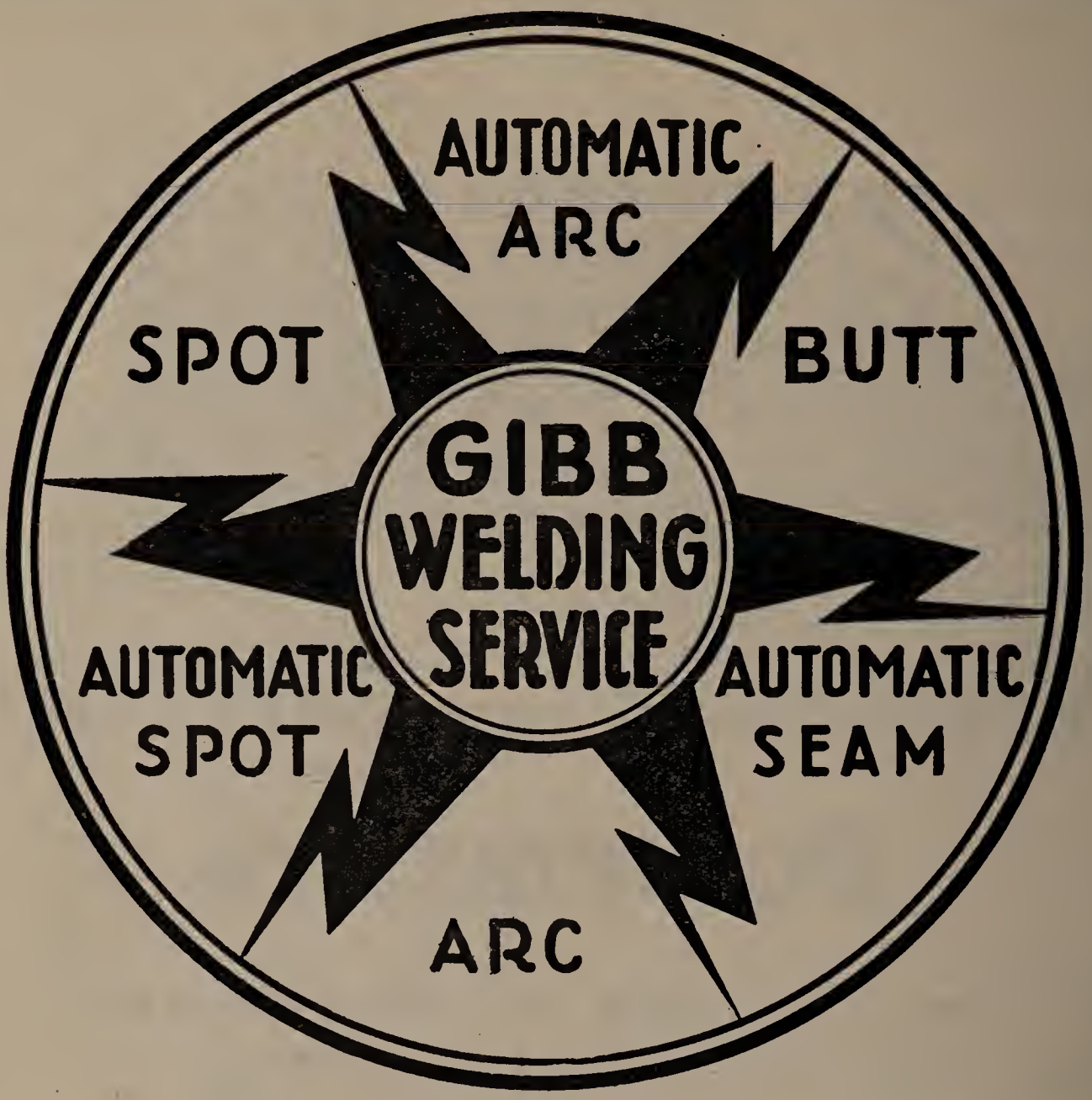
WE SPECIALIZE IN HIGHEST GRADE EQUIPMENTS EXCLUSIVELY.

AUTOMATIC CUTTING MACHINES

WE BUILD AUTOMATIC CUTTING MACHINES UP TO SIZES NEVER DREAMED OF BEFORE.

STANDARD CUTTING RANGES:

12	FEET	X 6	FEET
12	,,	X 4	,,
12	,,	X 2½	,,
6	,,	X 2½	,,



GIBB WELDING SERVICE EMBRACES

First—A complete line of Electrical Welding Equipment, making possible the best type machine for the job, taking all facts into account. There are cases when either an arc or a spot welder might be used; an arc or an automatic arc; an automatic arc or an automatic seam. Gibb Welding Service advises that which is most applicable.

Second—Sales Engineers who quickly recognize the nature of a job, and who from experience and an intimate knowledge of our complete line are in a position to determine the best solution.

Third—An up-to-date factory capable of following out the ideas of the engineer and his client.

Fourth—Installation Engineers of experience with welding machines and their application to production.

Tell us what you want to weld—let us give you the benefit of our experince. Experience is the safe director.

GIBB INSTRUMENT COMPANY

BAY CITY, MICH.

Phila.	Detroit	Cleveland	Chicago
521 Arch St.	Gnl. Mtrs. Bldg.	2104 Superior Ave.	428 Peoples Gas Bldg.

"ZEUS" A. C. Arc Welder

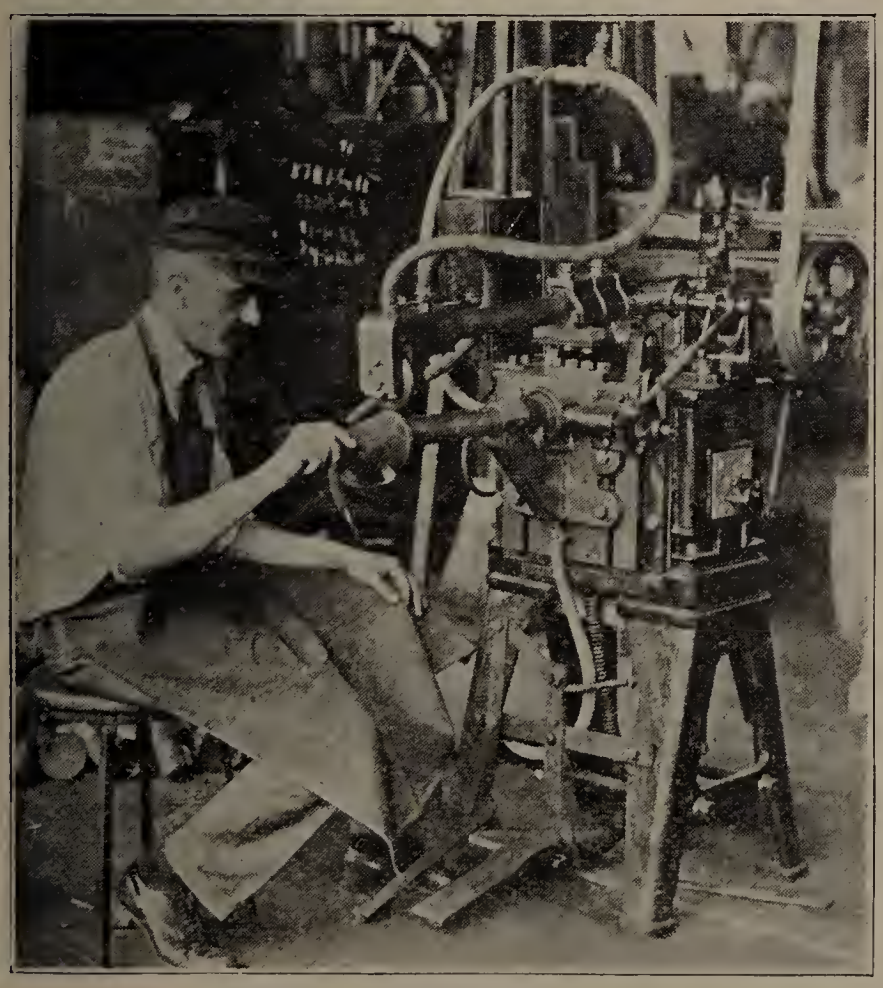
The ZEUS A. C. Arc Welder is a transformer specially designed for welding. The transformer is simplicity itself, consisting of an iron core and two coils built up of copper. The coils are known as primary and secondary coils. The primary, like the core, remains fixed; the secondary is raised or lowered by the regulator for the heat required for the work. This simplicity of construction makes the transformer the most dependable of electric apparatus.

Rotating parts, especially at high speed, mean wearing parts. Note the absence of wearing parts, or bearings to be oiled, or brushes to be renewed, or contacts to be cleaned.

The design and construction are such that no auxiliary or outside means is required for cooling.

Hand operated machines are made of 200 Amp. and 300 Amps., any voltage or frequency.

The 300 Amp. machine forms the electric welding unit of the **Gibb Automatic Arc Welder. The Gibb Automatic Arc Welder** itself is built to suit the product.



Seam Welding R. R. Torches

The fastest, and least expensive method existent to-day.

One of the accomplishments of Gibb Welding Service.

Gibb Instrument Co.

BAY CITY, MICH.

OXYGEN PRODUCING PLANTS

Air Liquefaction Process

Performance:

Continuous operation of two to four weeks.
Gas purity of 99% to 99.2%.

Operation Factors:

Air conversion—(the percentage of oxygen gas as obtained from the air)—15.2%.

Air conversion determines the operating efficiency and operating costs of an oxygen producing plant.

Simple and economical in operation.

Maximum production for the minimum expenditure of working materials.

Sizes:

2,500 cubic feet per day.
6,000 cubic feet per day.
17,000 cubic feet per day.
25,000 cubic feet per day.
42,000 cubic feet per day, or any mulitiple.

Construction:

Oxygen Producing plants consist of: PRECIPITATOR for the purification of the air from traces of carbon dioxide; AIR COMPRESSOR for the compression of the air; OIL and MOISTURE SEPARATOR; DRYING BATTERY for the reseparation of the carbon dioxide and drying of the air; AIR LIQUEFIER for the liquefaction and separation of the liquefied air into oxygen and nitrogen gas; GAS METER for the measuring of the gas produced. The air liquefier used in our plants is of the latest type containing features that allow a saving in operating costs.

Service:

Engineering service on all problems pertaining to the installation and operation of oxygen producing plants.

Complete stock of repair parts.

The experience of a firm manufacturing coppersmith and steel products for 16 years is at the service of the customer at all times.

Our plants are sold under positive guarantees as to cost efficiency, purity of gas and particularly, continuous operation.

Plants using 2,500 cubic feet of oxygen gas, or more, per day should be interested in securing our data on operating costs.

GROEN MFG. CO., INC.

4531-4537 Armitage Avenue **Chicago, Illinois**

The Solution of the Regulator Problem

No threads on either back or front cap to blow off. Double safety device. Diaphrams can not be ruptured. Adjustable seats which can be renewed from the back in three minutes. Loose diaphram which can be renewed in five minutes.

Harris Equipment for utilizing high temperatures from all combustible gases for welding and cutting purposes.

Pioneers

Write for catalog to

The Harris Calorific Company

CLEVELAND, OHIO

EVERYTHING FOR WELDING and CUTTING

Quick Shipment and Low Prices

REGO OUTFITS

COMPLETE plants for the generation of oxygen, hydrogen, nitrogen and acetylene for all industrial purposes. High purity is secured by I. O. C. installations. The I. O. C. trade mark has stood the test of time.

I.O.C. SYSTEM

We deliver Oxygen, Hydrogen and Fuel Gases in any quantity at the lowest prices compatible with the high purity of the product and dependable service.

Rego Torches, Regulators, and accessories in assembled outfits or single units for welding, cutting, lead burning, carbon burning. See pages 366 to 370 for complete information on REGO equipment.

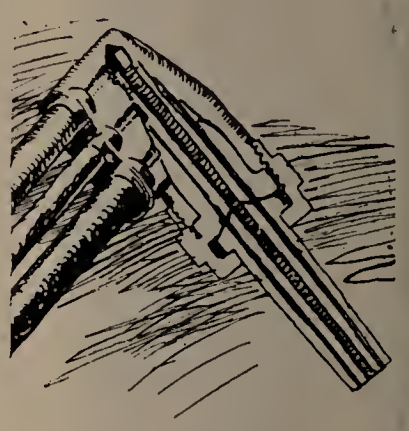
We carry a large stock of Welding Supplies, Wire, Rods in great variety, Accessories in high-grade materials, ready for immediate shipment.

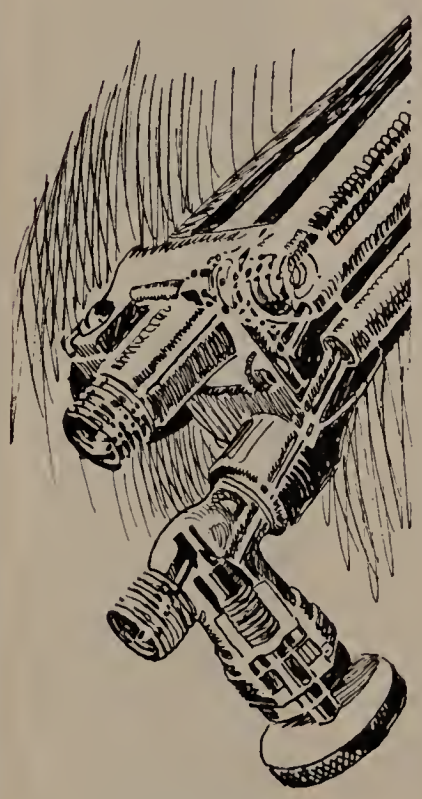
I. O. C. High Pressure Stud Valves are the only "free-from-packing" high-pressure valve on the market.

Miscellaneous Equipment for Gas Plants, Welding Shops and Laboratories — wherever high-pressure gases are used. Outfits for testing cylinders in accordance with I. C. C. specifications.

Let us work with you on your gas problems.

Write for literature.





REGO CUTTER

REGO TWO THNK TRUCKS

INTERNATIONAL OXYGEN CO.

American pioneer manufacturers of oxygen

NEWARK, N. J.

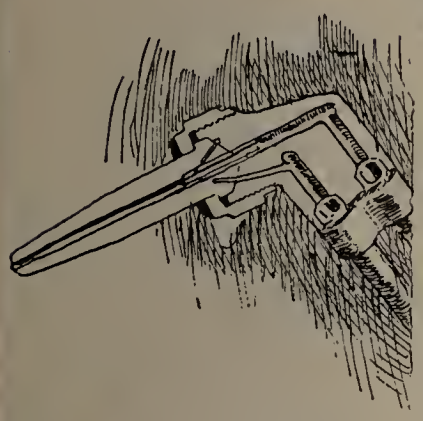
Branch Offices: New York, Pittsburgh and Toledo

REGO

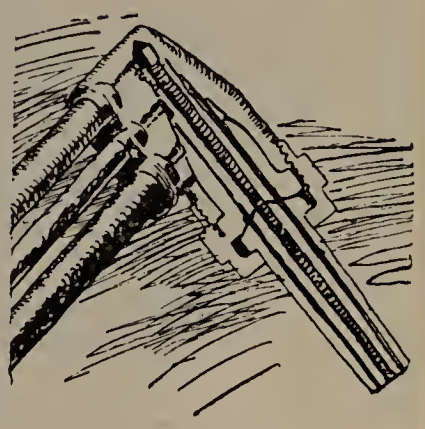
APPARATUS ACCESSORIES K-O SUPPLIES GASES

REGO

REGO PROPORTIONING OF GASES



REGO STURDY CONSTRUCTION



PRICE does not determine the value of an article from the standpoint of ECONOMY.

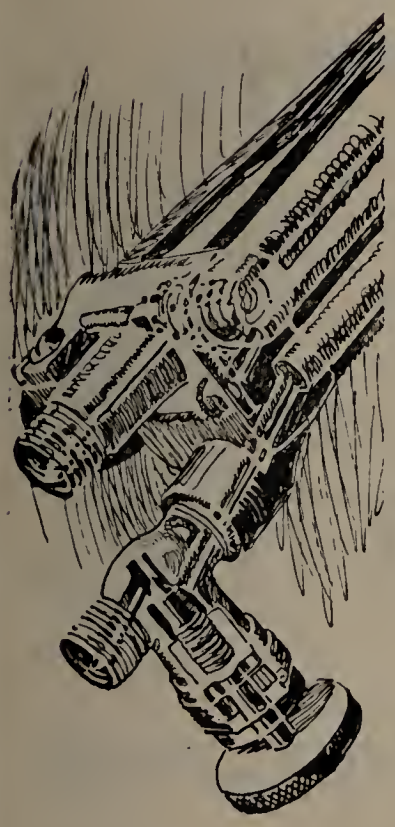
RESULTS ACCOMPLISHED in actual practice should govern the selection of commodities in the Oxy-Acetylene Field.

THE MOST EFFICIENT EQUIPMENT is that which will produce the desired results continuously with the least expense for gases and up-keep. FILLING MATERIALS should be free-flowing and of the proper analysis to produce sound welds free from hard spots and blow-holes. PURE GASES are cheaper in the long run.

REGO ALL COPPER WELDING TIPS

REGO ONE PIECE CUTTING TIPS

SERVICE—engineering advice in the application of the process or layout of an industrial installation; emergency repairs and quick replacement of parts; prompt shipment of all orders—is invaluable to the user and adds much to the intrinsic value of each item.



RIVET CUTTING TIPS

THE FACILITIES OF THE KENTUCKY OXYGEN-HYDROGEN COMPANY—including Manufacture, Engineering, Sales and Service Departments—are devoted to enabling users of the Welding and Cutting Processes to secure the GREATEST POSSIBLE BENEFIT WITH THE LEAST EXPENDITURE OF MONEY.

We solicit your inquiries

Kentucky Oxygen-Hydrogen Company

Incorporated

1252 So. Logan St., Louisville, Ky.

Distributors in Principal Cities

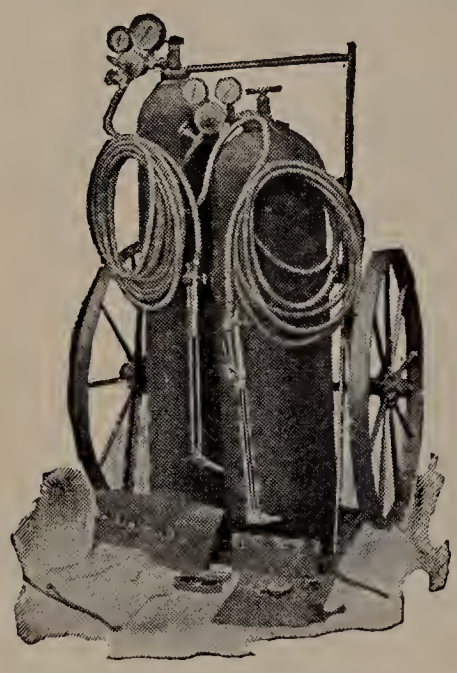
K-G Welding & Cutting Co., Inc.

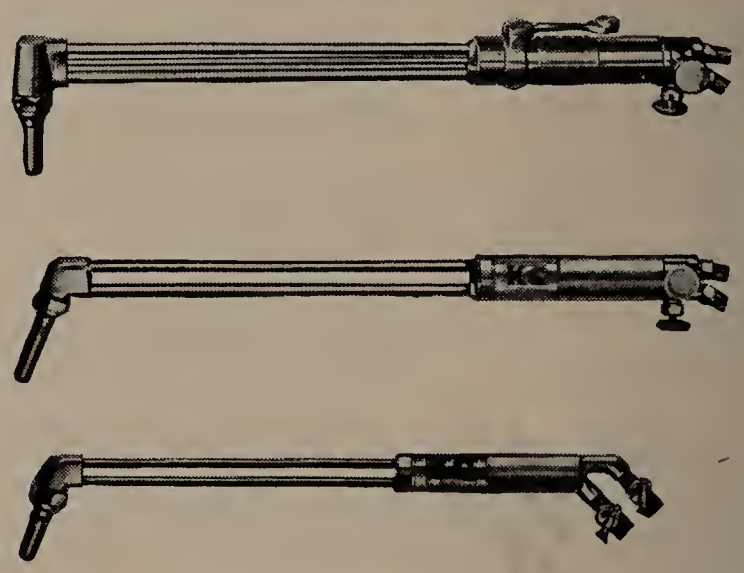
Home Office and Factory, 556 West 34th St., N. Y. City

DISTRIBUTORS IN THE FOLLOWING CITIES:

Binghamton, N. Y.
Syracuse, N. Y.
Staten Island, N. Y.
Yonkers, N. Y.
Albany, N. Y.
Trinidad, Colo.
Boston, Mass.
Bridgeport, Conn.
New Haven, Conn.
Elizabeth, N. J.
Philadelphia, Pa.
Spencer, Iowa.
Pittsburgh, Pa.
Baltimore, Md.
Allentown, Pa.
Detroit, Mich.
Chicago, Ill.
West Alexandria, Ohio.

Torches, Complete Units Installations and Supplies





COMPRESSED GAS WELDING and CUTTING

The K-G Welding and Cutting Equipment

The K-G Apparatus throughout is the most durable of its kind made today. It is low in initial cost, low in operation cost, low in maintenance charges. Competition and comparison under all conditions are invited. The complete K-G Equipment mounted on a portable truck, is illustrated above, together with the standard sizes of K-G Torches for cutting and welding.

SUPPLIES FOR WELDING AND CUTTING

REGO OUTFIT

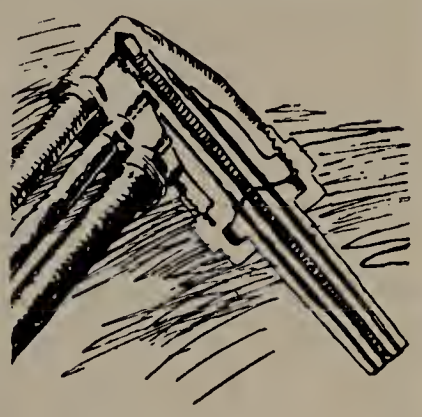
We aim to give you the best

SERVICE
QUALITY
PRICE

on

Oxygen—Hydrogen
Acetylene—Supplies

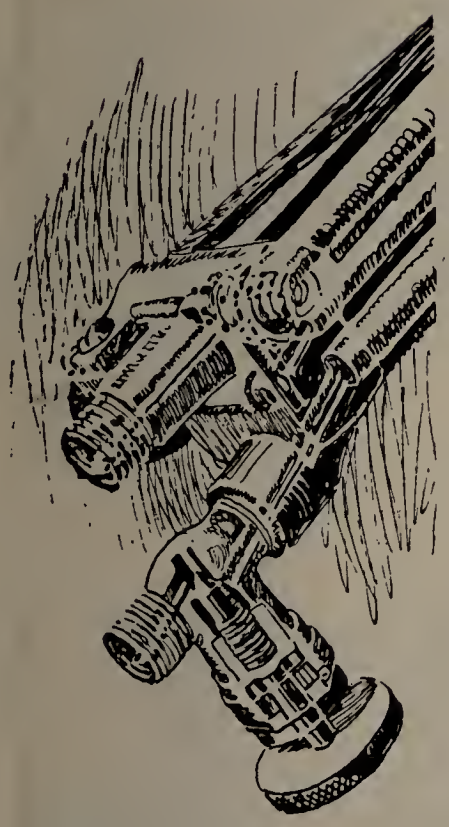
REGO STURDY CONSTRUCTION



REGO ONE PIECE TIPS

REGO

Welding
and
Cutting
Equipment
Generators
Preheaters



REGO CUTTER

For full information regarding Rego apparatus see Pages 366 to 370

REGO REGULATOR

MEMPHIS OXYGEN COMPANY

682 So. Main St. Memphis, Tenn.

LINCOLN ARC WELDER

Lincoln Pioneers in Arc Welding No buyer of welding equipment can afford to overlook the experience of The Lincoln Electric Co. in the welding field. As pioneers and specialists in this process, they have developed a skill both in design of apparatus and in its application which is of greatest value to the user and which cannot be obtained elsewhere.

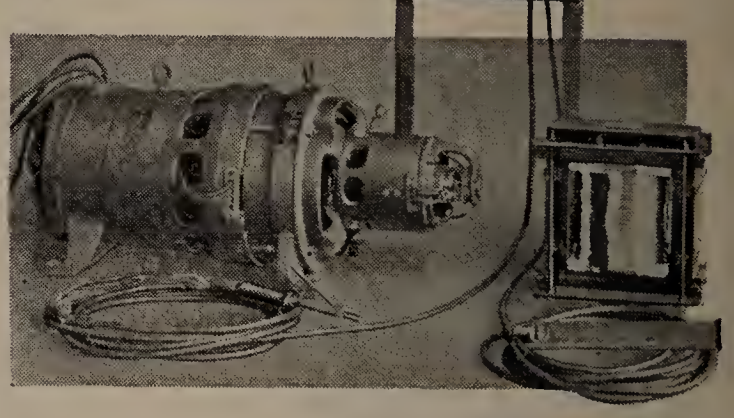
Service In each of its 14 branches, The Lincoln Electric Co. maintains men who specialize **exclusively** in arc welding. They are practical men able to estimate costs, install plants and insure the successful use of Lincoln Equipment. Their services are free to any one interested in arc welding.

Power Required Lincoln Arc Welders are built in types suitable for operation by (1) Electric Current (Direct or Alternating) (2) Gas Engine—direct connected (3) Belt Power (see illustrations).

Sizes Lincoln Arc Welders are designed in various sizes to deliver a welding current from 150 to 600 amperes.

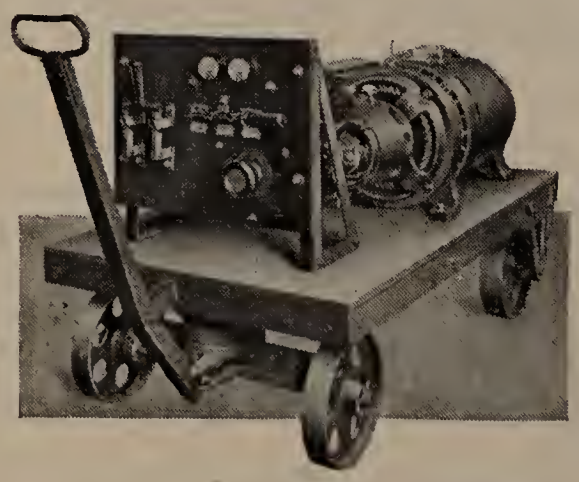
Styles of Mount Lincoln Arc Welders are mounted in several styles, according to the work for which they are used, (1) Stationary Panel Board Welders, (2) Portable Welder on Truck, (3) Gas Engine Driven, (for mounting on motor truck, skids, or shop truck), (4) Automatic Welder as described on next page.

Standard Lincoln Arc Welder with stationary panel furnished for direct or alternating current in sizes 150 to 600 amperes.

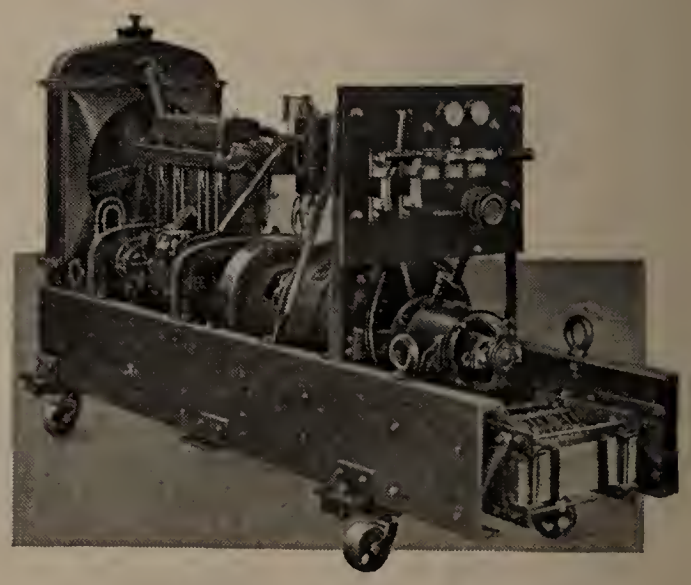


Speed of Welding The Lincoln Arc Welder will do more welding work per day under practical working conditions than any other type of welder made. This we are prepared to submit to competitive test. The speed of Lincoln Welder is due to the following features of its design.

Ease of Operation The arc produced by the Lincoln Welder is steady and does not "go out" or "sputter" with the slight variation of the welder's hand. The operator welds rapidly without cramp or fatigue.



Lincoln Arc Welder Portable Type for railroad shop and similar uses requiring portable outfit. Can be plugged in on any line where 5 horsepower motor could be used.



Lincoln Arc Welder direct connected to gas engine. Portable outfit for mounting on motor truck or boat.

Laminated Frame The entire frame of the Lincoln Welder is built up of steel laminations. The electrician will understand that this permits the very rapid change of the magnetic field and a quick increase or decrease of the amount of current according to the demands of the arc. This makes the arc steadier and less likely to "go out."

The Lincoln Stabilizer This Stabilizer, which is of exclusive design, still further steadies the arc by acting as a reservoir for the energy storing it up when the demand is not so great and giving it out when the arc requires it. A change in the length of arc due to the movement of hand or a rough welding surface does not break the arc.

Simplicity Compare the illustrations of the Lincoln Welder with those of any other make and note how simple the Lincoln apparatus is. Every part of it is standard electrical equipment which any practical electrician can understand and repair should occasion arise.

Economy of Current There is no resistance used in the circuit of Lincoln Arc Welders to cut current down to welding voltage. The Lincoln is a "variable voltage" machine delivering at all times the exact voltage needed at the arc. No current is wasted in the Lincoln Welder.

The Lincoln Automatic Welder This is the most recent development in electric arc welding and has already made remarkable records in speed of welding and reduction of costs.

This type of Lincoln Arc Welder is especially suited to production jobs where a large number of pieces of the same character are to be produced by welding. It is being successfully applied to gasoline tanks, tanks, steel cases, range boilers, steel barrels and similar classes of work.

The sheets of metal to be welded are clamped tightly in position either with or without a metal filling rod between the edges, depending upon the class of work.

A carbon electrode arc is brought to play on these edges thoroughly melting them and welding them together.

The carbon electrode which forms this arc is gradually fed forward by a mechanical driving apparatus as the welding takes place. As the carbon pencil is burned away, it is also fed forward by the same apparatus so that the entire operation of welding is automatic after the pieces are once set in place and the welding started.

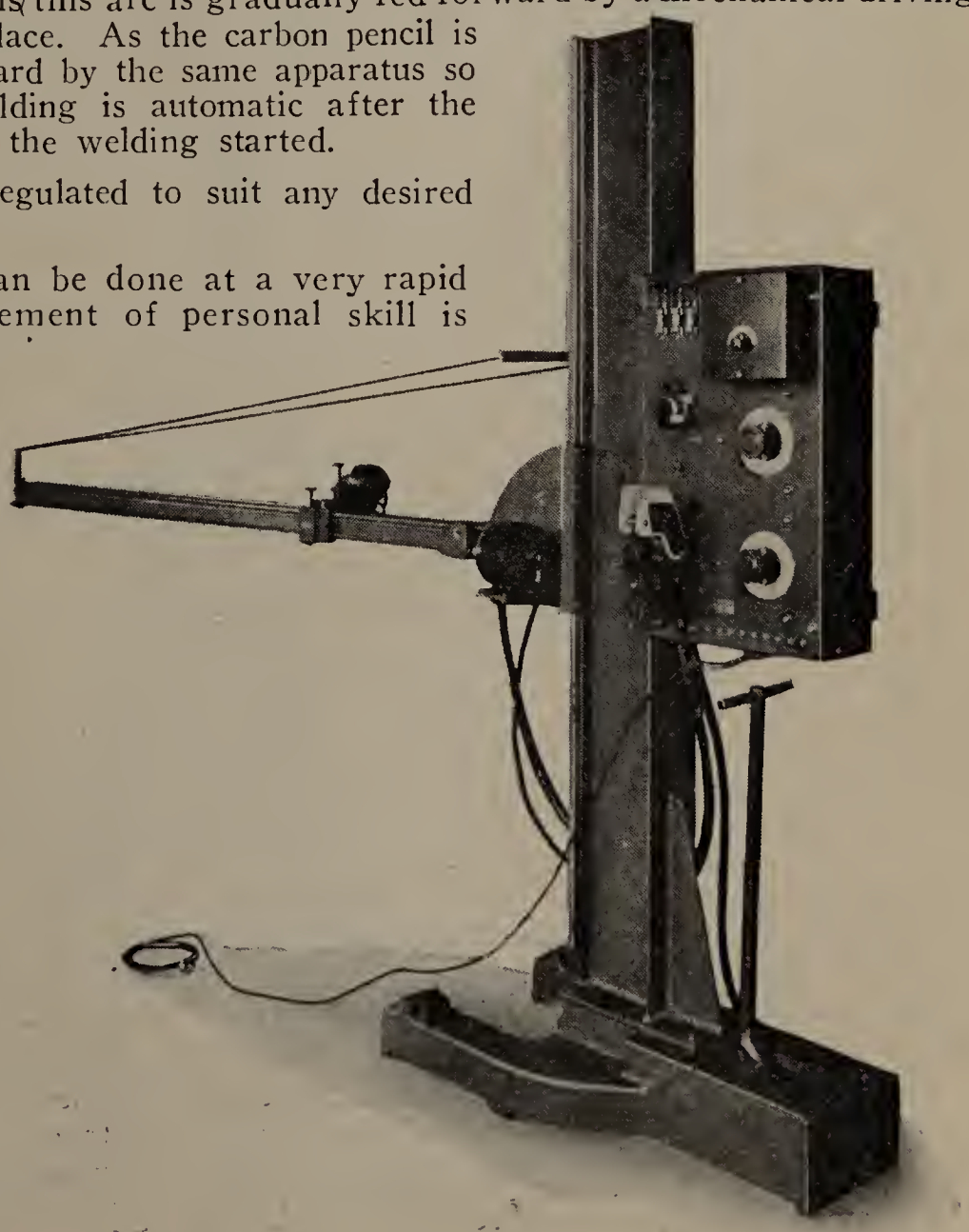
The driving apparatus can be regulated to suit any desired speed of welding.

With this apparatus welding can be done at a very rapid rate and low cost and the element of personal skill is largely eliminated.

Costs as low as 1 cent per foot have been secured on 14 gauge metal.

Firms who believe that they have a product which could be handled successfully on this type of machine, are invited to confer with Lincoln Engineers and to arrange for demonstration and test of this Automatic Welder.

Descriptive Bulletins on Request



The Lincoln Electric Co.

General Offices and Factory

Cleveland, Ohio

Offices and Agencies in all Principal Cities.

The Linde Air Products Co.

Carbide and Carbon Building, 30 East 42nd Street
NEW YORK CITY

LINDE OXYGEN

Well-Organized Chain of Distributing Stations:

Linde Oxygen is available in every manufacturing district in the country. A well-organized system of distributing stations —see list on next page—provides dependable service to Oxygen users.

Thirty-one plants and fifty-eight warehouses make up this great service chain, every link of which has behind it the strength and facilities of the entire chain.

Advice and Assistance on Problems Involving Use of Oxygen:

Linde service goes beyond the mere supplying of its product; it includes carefully planned methods of applying information, advice and assistance in the field to individual user's problems and needs.

Linde thus offers to its users the fruits of the experience gained by intensive contact with the development of the Oxy-Acetylene Process through the growing chain of Linde District Sales Offices as listed on opposite page. This is the logical development of Linde's desire to give its patrons every facility and service in the use of Linde products.

It is because of these facts and because the Linde organization is constantly working to enlarge its usefulness and improve its service that Linde has become the largest producer of Oxygen in the world.

For not only engineering advice and assistance in the field on your individual problem, but for information regarding our latest sales and service plans users of Linde Oxygen are requested to keep in close touch with Linde District Sales Offices.

Form in Which Linde Oxygen Comes to You

Linde Oxygen comes to you in cylinders of two capacities. Our standard type contains 220 cubic feet and is the size generally preferred because of economy in freight and handling.

We can, however, supply 110 cubic feet capacity cylinders if your consumption does not justify the use of the larger size.

Our Customers Buy Oxygen—not the Cylinders:

Linde customers are entitled to the free use of as many cylinders as are required in the operation of their business, with the understanding that they are to be returned within 30 days after shipment.

Where cylinders are kept longer than 30 days, the company reserves the right to charge a rental of 25 cents per week per cylinder regardless of size.

This arrangement, whereby the Company retains and assumes the responsibility of ownership of cylinders, relieves the users of all expense incidental to the purchase of cylinders and the possible trouble or bother incidental to the compliance with complex Inter-State Commerce and shipping regulations.

The Cost of Linde Oxygen:

The prices we can quote will vary slightly at different points on account of freight, cartage, etc. We quote all prices f.o.b. at company's distributing points—customers to prepay transportation charges when returning "empties." We quote special reduced rates where large quantities of oxygen are required at regular intervals.

No oxygen user, large or small, should close an arrangement for oxygen supply without first securing 1923 prices and terms from the nearest Linde District Sales Office, located in any one of the following cities.

Atlanta	Los Angeles
Baltimore	Milwaukee
Boston	New Orleans
Buffalo	New York
Chicago	Philadelphia
Cleveland	Pittsburgh
Dallas	San Francisco
Detroit	Seattle
Kansas City	St. Louis

THE LARGEST PRODUCER OF OXYGEN IN THE WORLD

SHIPPING POINTS FROM WHICH LINDE OXYGEN MAY BE ORDERED

Your order should be forwarded addressed to "THE LINDE AIR PRODUCTS CO." at any of the following Distributing Stations.

DISTRIBUTING STATIONS

ALABAMA
*Birmingham .....10th Ave. & 28th St.
Mobile...16 South Commerce St.

ARKANSAS
Little Rock.....812 East 2d St.

COLORADO
*Denver ..So. B'way & Exposition Ave.

CONNECTICUT
Hartford.....412 Trumbull St.

DISTRICT OF COLUMBIA
Washington 9th St. & Maryland Ave., S. W.

FLORIDA
Jacksonville...1008 East Bay St.

GEORGIA
*Atlanta ..Pylant St. & Southern R. R.
Savannah.312-316 Williamson St.

ILLINOIS
*Chicago..(Central Mfg. Dist.) .....3633 So. Wall St.
East St. Louis....700 Broadway
Peoria ....721-731 So. Washington St.

INDIANA
*East Chicago ....Kennedy Ave. & 145th St.
Fort Wayne..414 E. Columbia St.
Hammond ...C. I. & L. Ry. & Harble St.
*Indianapolis .....2919 Roosevelt Ave.
Terre Haute.....541 No. 5th St.

IOWA
Davenport.....500 S. Howell St.
Des Moines.532 S. W. Seventh St.

KANSAS
Wichita....115 No. Meade Ave.

KENTUCKY
Louisville.....126 E. Main St.

LOUISIANA
*New Orleans .....432 No. Anthony St.
Shreveport .....Lake & Commerce Sts.

MARYLAND
*Baltimore ....25th St. & Montibello Ave.

MASSACHUSETTS
*Boston.....K. & E. First St.
Springfield ..Pasco Road, Indian Orchard
*Worcester..961 Southbridge St.

MICHIGAN
*Detroit ..St. Aubin Ave. & Newton St.
Grand Rapids .....500 Shawmut St., N. W.
Muskegon..301 W. Western Ave.

MINNESOTA
Duluth ..7th Ave., W. & Railroad St.
*Minneapolis .....1809 E. Hennepin Ave.

MISSOURI
*No. Kansas City.....14th & Charlotte Sts.
*St. Louis.4218 Forest Park Blvd.

NEBRASKA
*Omaha.....56th & Centre Sts.

NEW JERSEY
*Elizabeth..... Linden Road
Newark (Callers only).....251 Ridgewood Ave.

NEW YORK
Albany.....108 Third Ave.
*Brooklyn.....475 Driggs Ave.
*Buffalo...Broadway & Ideal St.
New York.....637 W. 50th St.
Rochester.....55 Railroad St.
*Utica...Walnut & Schuyler Sts.

OHIO
Canton..638 Mulberry Rd., S. E.
*Cincinnati .....Stanton & Melish Aves.
*Cleveland ....E. 73rd St. & Bittern Ave.
Columbus.....320 Dublin Ave.
Dayton.....523 E. First St.
Lima.....338 E. High St.
Marion...160 McWilliams Court
Toledo.....414 S. Erie St.
*Youngstown.....601 Jones St.

OKLAHOMA
Oklahoma City .....1-3-5 E. Grand Ave.
Tulsa.....1-11 No. Boulder St.

PENNSYLVANIA
Allentown.....311 Gordon St.
Erie.....1502 Sassafras St.
Harrisburg..239 So. Cameron St.
Johnstown ..... Messinger St. & B. & O. R. R.
*Philadelphia .....18th & Cambria Sts.
*Pittsburgh.Lincoln & Tabor Sts.
Reading..Front & Franklin Sts
Scranton...Penn Ave. & Vine St.
*Trafford .....

RHODE ISLAND
Providence .....
..Allens Ave., Foot Oxford St.

TENNESSEE
Chattanooga.212 to 238 King St.
Memphis.....475 N. Main St.
Nashville.210 Tenth Ave., North

TEXAS
*Dallas..Harwood & Coombs St.
Galveston.Avenue "B" & 15th St.
Houston .....Live Oak St. & H. B. & T. R. R.
Port Arthur..231 Fort Worth St.
San Antonio...115 S. Medina St.
Wichita Falls....810 Scott Ave.

VIRGINIA
*Norfolk .....Colonial Ave. & 22nd St.
Richmond .....

WEST VIRGINIA
Charleston .....Broad St. & K. & M. Ry.
Wheeling .....Main, South & 16th Sts.

WISCONSIN
Manitowoc.....810 Quay St.
*Milwaukee..3623 National Ave.

WYOMING
Casper.....218 Industrial Ave.

PACIFIC COAST

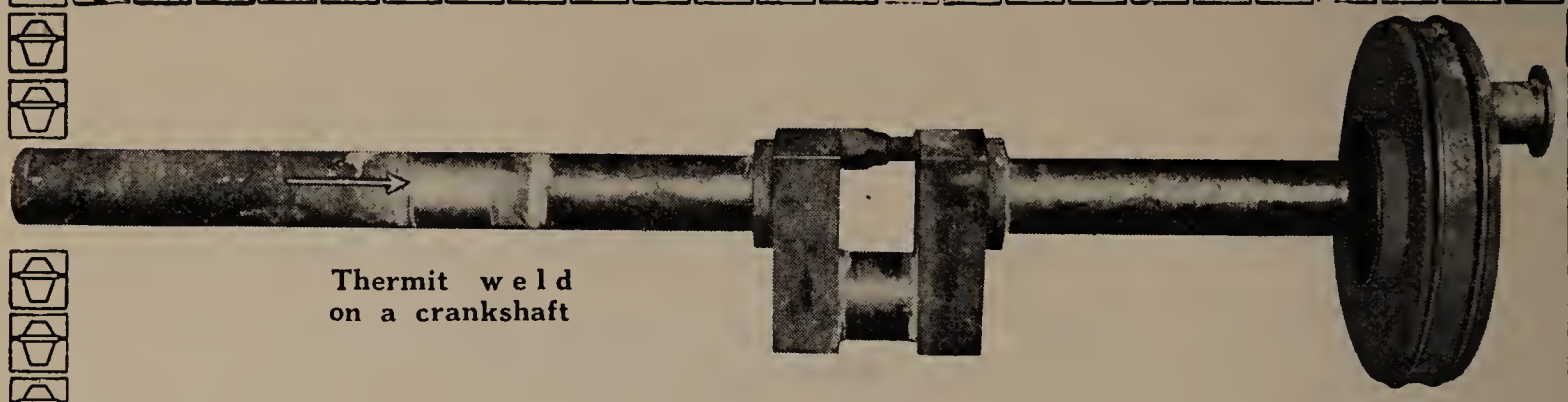
CALIFORNIA
*Emeryville, Oakland .....452 Watts St.
*Los Angeles..1405 Mission Road
San Diego.....301 3rd St.
San Francisco.8th & Brannon Sts.
So. San Francisco.....

OREGON
Portland.....15th & Hoyt Sts.

UTAH
Salt Lake City.....118 West Second South St.

WASHINGTON
*Seattle .....Alaska St. & 8th Ave., South
Spokane.....121 So. Madison St.

*Indicates Plants.



Thermit weld on a crankshaft

THERMIT WELDING

1. **Miscellaneous Repairs.** Quick, economical and permanent repairs of crank shafts, housings, pinion teeth, press frames, roll necks, shears, stern frames of vessels and many other sections.

2. **Thermit Locomotive Repairs.** Most reliable method of repairing frames; also most economical methods, even for light frames.

3. **Thermit Rail Welding.** Absolutely eliminates rail joints in paved streets. First cost is last cost; first cost is no greater on the average than that of any other rail joint.

4. **Thermit Pipe Welding.** Makes permanent joints in leaky, high pressure steam, hydraulic and compressed air pipe lines, pipe coils of chemical and refrigerating plants, also of cracking stills in oil refineries.

If you have broken something, wire us or telephone our nearest office.

Send for Pamphlet No. 1753

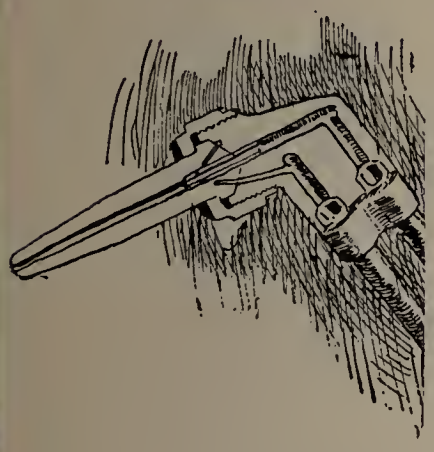
Metal & Thermit Corporation

120 BROADWAY, NEW YORK

Chicago Pittsburgh Boston So. San Francisco Toronto

Cutting and Welding Service

REGO PROPORTIONING OF GASES

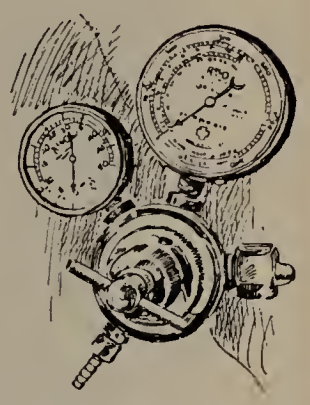


QUALITY is built into every piece of REGO apparatus.

CORRECT DESIGN is insured by the important basic patents held by REGO.

SERVICE is guaranteed by the reputation and rating of its manufacturers, The Bastian-Blessing Co. (Complete data on pages 366 to 370.)

THAT is why we are proud to be West Coast Service Distributors of REGO Equipment.



REGO REGULATOR

Torches

Complete outfits

Regulators

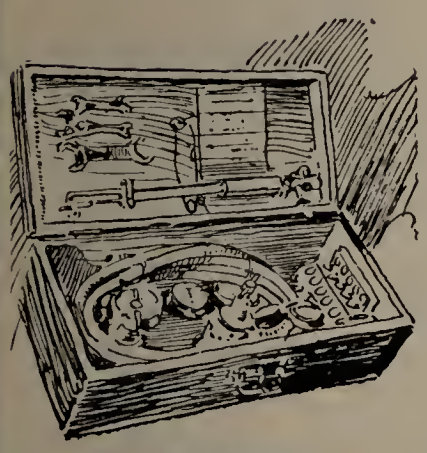
Generators

Fluxes

Gauges

Goggles

and all accessories for welding and cutting



REGO OUTFITS

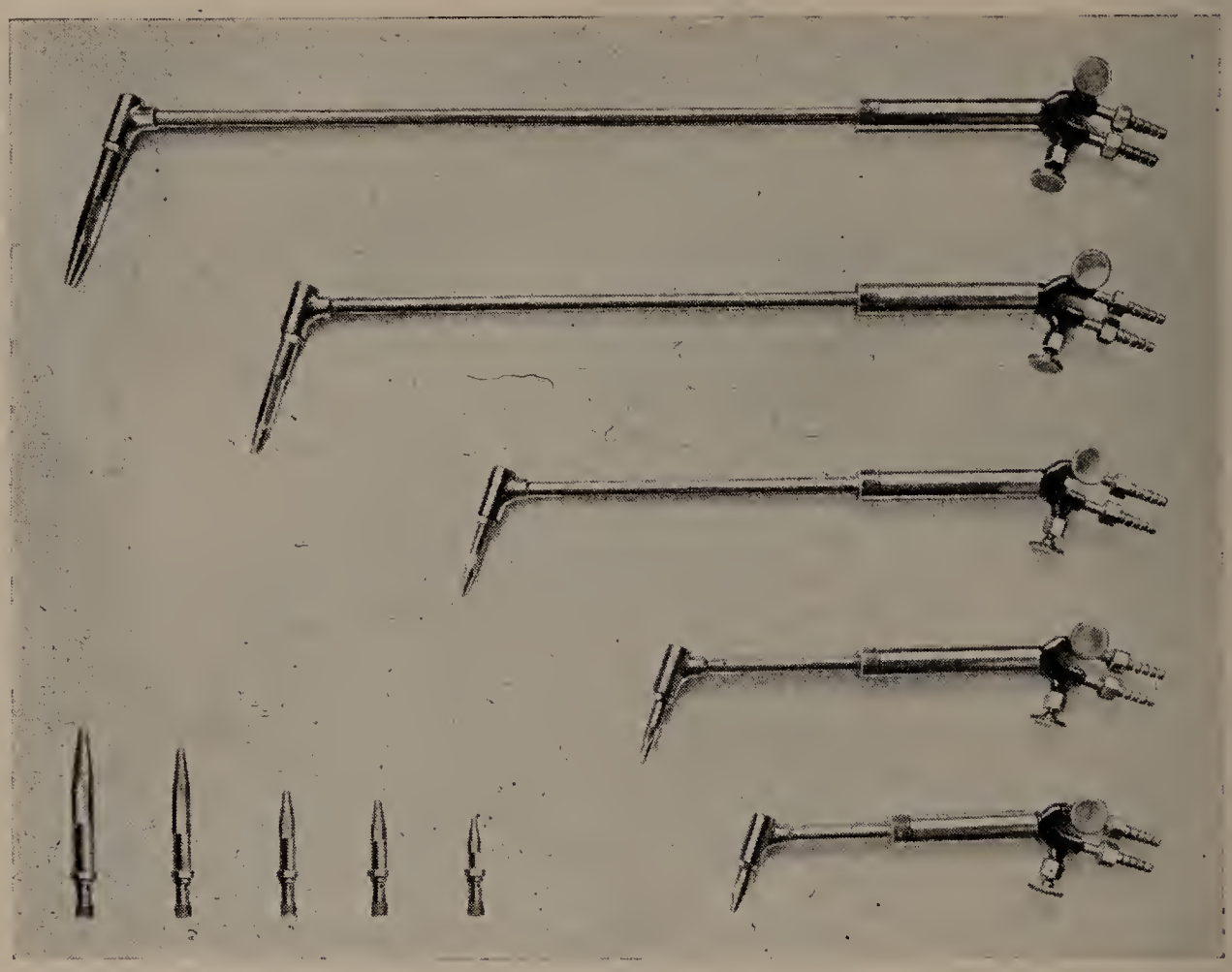
WE maintain a complete service department for the repair of old equipment and for new installations.

BRING us your welding problems. Let us quote you on new equipment.

THE NOBLE COMPANY

1801-1809 So. Figueroa St. Los Angeles, Calif.

Oxweld



Welding Blowpipes

The Oxweld blowpipe is a high efficiency torch designed to give equally good results when used with either low or high pressure acetylene systems.

The basic operating principle of the blowpipe is that of the injector, which utilizes the high velocity of oxygen, under predetermined pressures, to syphon into intimate mixture the correct proportion of acetylene, the latter gas being under the same low pressure for all sizes of tips. This system in itself offers an automatic regulation of gases and thereby maintains a blowpipe flame of constant neutrality. The thoroughness of the mixture of the gases is evidenced by the oxygen-acetylene ratio 1.07: 1.00 which approximates, very closely, the theoretical. The handles are substantially constructed and are manufactured in five lengths. The welding head is designed for the interchange of ten graduated sizes of tips for welding metal from $\frac{1}{32}$" up to any thickness.

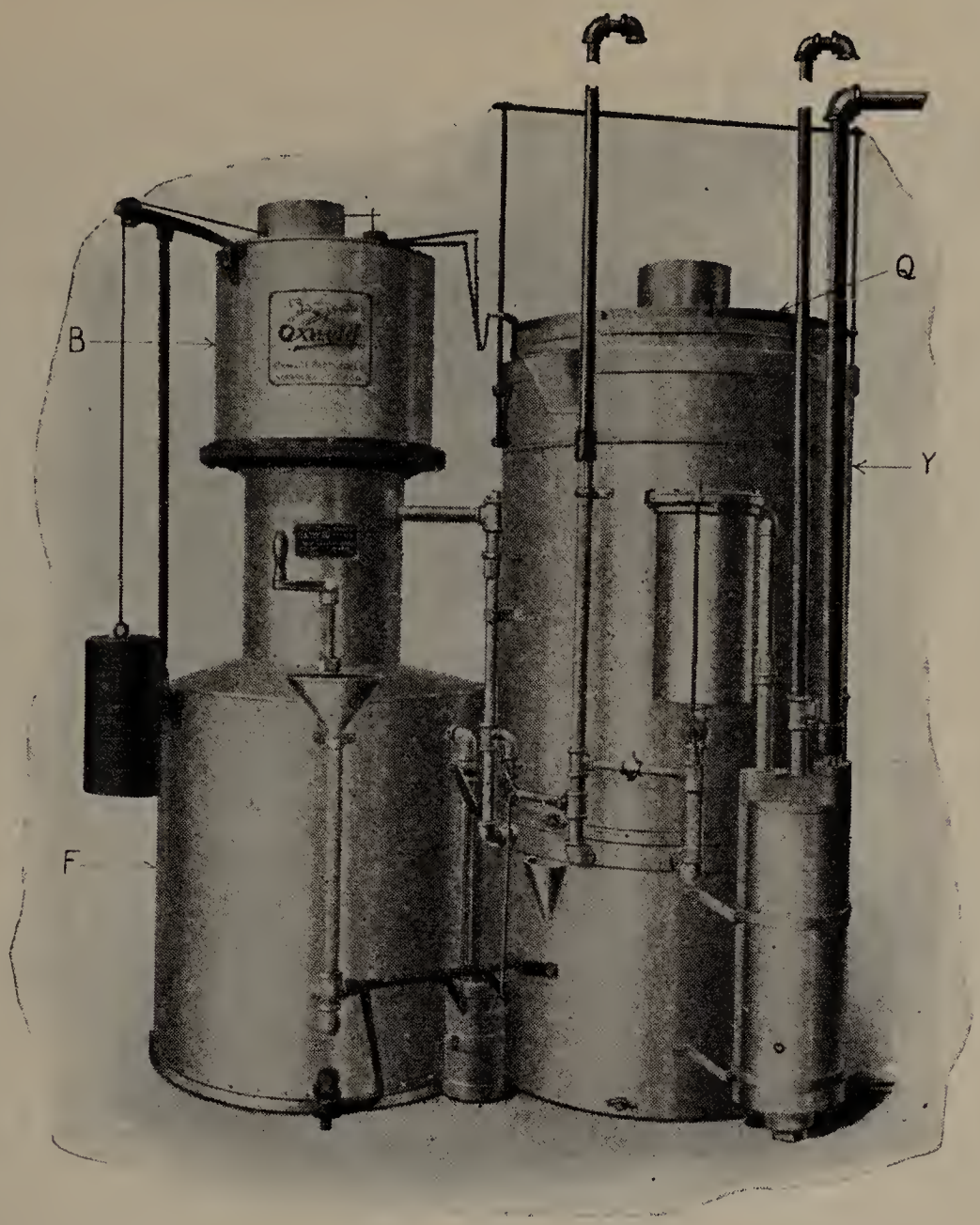
Cutting Blowpipes

Oxweld cutting blowpipes are made in various models suited to every cutting operation. There are four sizes of cutting nozzles designed for cutting metal from the thinest sheets up to sections more than a foot in thickness. In addition to this there is a special type for rivet head cutting.

The same injector system used in the welding blowpipe is utilized to produce the preheating flames. There are six of these flames arranged in a circle around the cutting oxygen jet. They are so proportioned and inclined that the maximum preheating effect is obtained. Also, by this circular arrangement, the preheating is always in advance of the cutting jet. The cutting valve is specially designed to withstand hard service. It is of the lever type, opened and latched by thumb pressure. Two piece cutting nozzles are used, the internal being made of bronze and the external of pure copper. This combination produces a nozzle of greatest cutting efficiency and durability.

GENERATORS

The Oxweld low-pressure generator is the one that produces acetylene at a pressure less than one pound. Because of this low pressure it is possible to utilize a gasometer for the storage of the gas and to regulate and control the operation of the generator. In a generator of this type the gas pressure remains constant, no regulating or reducing device being necessary. The low pressure generator is designed to be used with the injector type blowpipes, (described on the preceding page). A small hydraulic back pressure valve is used at each blowpipe outlet as a seal to prevent a reverse flow of gas. Oxweld manufactures low pressure generators in all types adapted to use in industrial plants. The one illustrated is a typical simplex model. A duplex model is also built which consists of two generating chambers connected to one gasometer. In this type one generating chamber can be operated while the other is being cleaned or charged, which assures continuous gas supply.



Oxweld Low Pressure Single Type Generator

NOTE— The equipment previously described comprises a typical installation for plants where acetylene is generated and used on the premises. Oxweld blowpipes are equally efficient when used with dissolved acetylene in cylinders, and so used are conveniently assembled with the cylinders on a light but sturdy two-wheel truck manufactured especially for the purpose.

OXWELD ACETYLENE COMPANY

Long Island City Chicago San Francisco

Oxweld

WELDING AND CUTTING APPARATUS

World's Largest Manufacturers of Welding and Cutting Equipment

EVEREADY

Welding and Cutting OUTFITS

All their name implies

Oxweld Low Pressure Single Type Generator

Eveready Welding and Cutting Outfits are designed for use with compressed oxygen and dissolved acteylene in the familiar portable steel cylinders. Many thousands of these outfits are in successful use throughout the United States and Canada. They are moderate in price and satisfactorily meet every requirement for equipment of their type.

Welding

For general all-around use, the H-1 Welding Outfit is recommended. It will do practically any job within the range of the oxy-acteylene process, and because of its simplicity, portability and absolute safety, it is very popular with garages, blacksmith shops, machine shops, job welding shops, sheet metal and structural iron shops and in manufacturing plants. By adding only a few simple pieces of apparatus, a combination outfit is available for cutting, decarbonizing and lead burning.

Eveready Type H-1 Welding Blowpipe

Cutting

Eveready Type K-2 Cutting Blowpipe is built to withstand rough usage, great sturdiness being skilfully combined with unusual lightness, nicety of balance and all-around handiness. It is correctly designed, accurately machined and made of the best materials throughout. All parts are readily interchangeable. They include four sizes of nozzles suited to cutting steel and wrought iron up to ten inches in thickness. A special nozzle for straight-line cutting or beveling and a rivet cutting nozzle are also made and are included in the outfit when specially ordered.

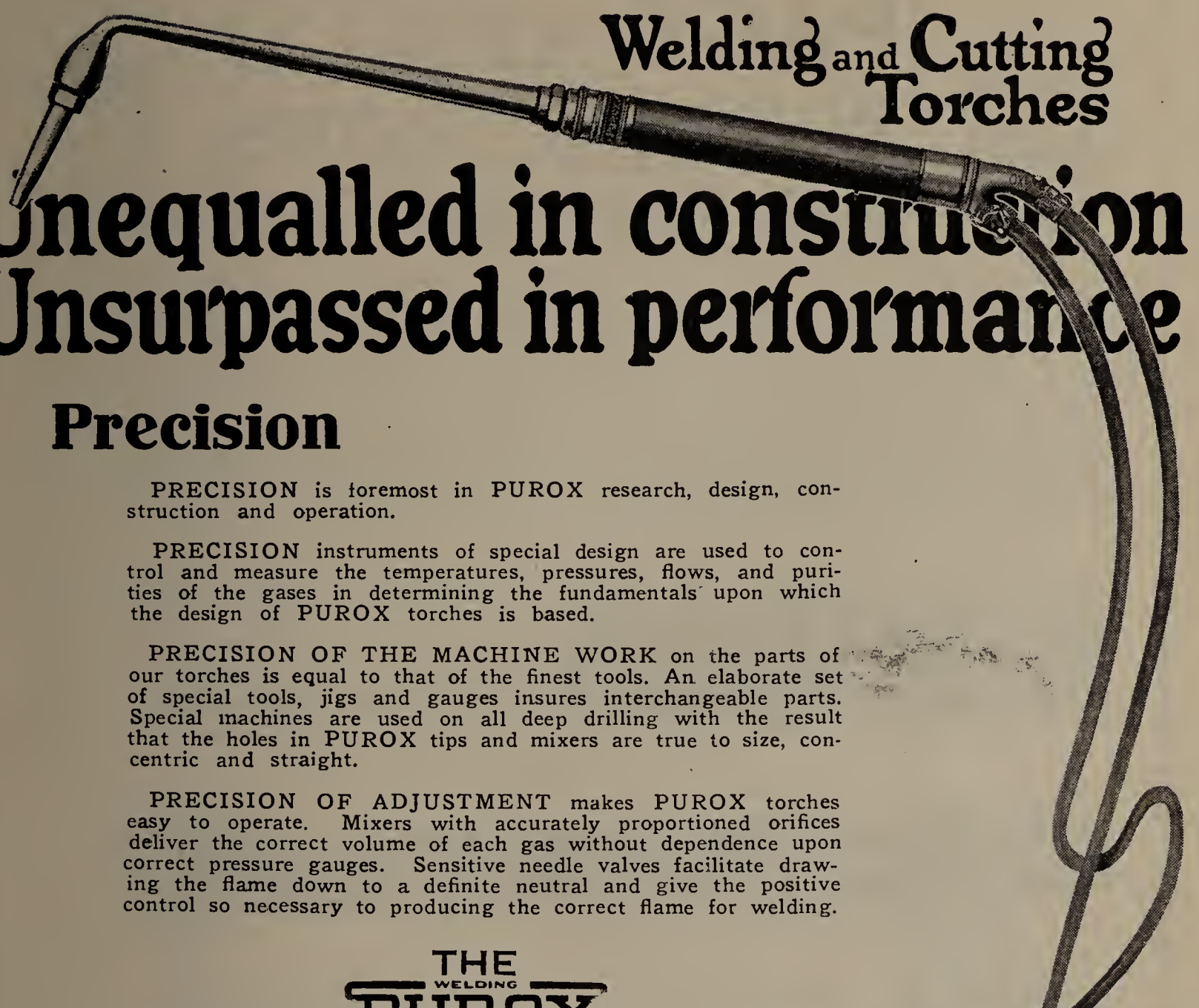
Made by

OXWELD ACETYLENE CO.

Long Island City - Chicago
San Francisco

Sold by Active Jobbers Everywhere

World's Largest Manufacturers of Welding and Cutting Equipment



Welding and Cutting Torches

Unequalled in construction Unsurpassed in performance

Precision

PRECISION is foremost in PUROX research, design, construction and operation.

PRECISION instruments of special design are used to control and measure the temperatures, pressures, flows, and purities of the gases in determining the fundamentals upon which the design of PUROX torches is based.

PRECISION OF THE MACHINE WORK on the parts of our torches is equal to that of the finest tools. An elaborate set of special tools, jigs and gauges insures interchangeable parts. Special machines are used on all deep drilling with the result that the holes in PUROX tips and mixers are true to size, concentric and straight.

PRECISION OF ADJUSTMENT makes PUROX torches easy to operate. Mixers with accurately proportioned orifices deliver the correct volume of each gas without dependence upon correct pressure gauges. Sensitive needle valves facilitate drawing the flame down to a definite neutral and give the positive control so necessary to producing the correct flame for welding.

THE WELDING PUROX CUTTING COMPANY

2305 E. 52nd St.
Los Angeles, Cal.

3030 Huron St.
Denver, Colo.

1135 Third St.
Oakland, Calif.

2020 East 22nd St.
Cleveland, Ohio

362 Pierpont Ave.
Salt Lake City, Utah

14 East 13th St.
Kansas City, Mo.

2920 First Ave., So.
Seattle, Wash.

620 E. Hancock St.
Detroit, Mich.

1200 Sheffield St.
N.S. Pittsburgh, Pa.

Representatives throughout the United States, Canada and Mexico

PAGE-ARMCO WELDING RODS and ELECTRODES

AMERICAN INGOT IRON

Uses—Wherever welding is recommended on Mild Steel either for production or repairs by the Electric or Gas process, Page-Armco Electrodes and Gas Welding Rods will fulfill to the highest degree every requirement demanded of a dependable welding material.

Analysis—Page-Armco Gas Welding Rods and Electrodes are guaranteed Commercially Pure Iron, the carbon content being maximum .02. The metal analyzed for nine elements, carbon, manganese, phosphorus, sulphur, silicon, copper, oxygen, hydrogen and nitrogen, gives a total of only 16/100 of 1% impurities; the remainder 99.84% is pure iron free from non-metallic inclusions such as slag presenting a solid uniform pure metal which will give a weld deposit of the same purity.

At Left—Electrodes

Below—Gas Welding Rods

Page-Armco Welding Wire in bundles or coils, wrapped in burlap for shipping

Page-Armco Electrodes on Metal Reels containing 200 lbs. of wire for General Electric automatic and semi-automatic arc welder

Sizes

WELDING RODS

Page-Armco Oxy-acetylene Copper Coated Welding Rods are furnished in the following sizes. Packed in 50 pound bundles or in coils.

Diameter—$\frac{1}{16}$ in., $\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{5}{32}$ in., $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{5}{16}$ in. and $\frac{3}{8}$ in.

Length—36 inches.

Yellow Tag denotes Gas Welding Rods. Ends of rods colored yellow.

ELECTRODES

Page-Armco Electrodes are furnished in the following sizes. Packed in 50 pound Bundles or in Coils.

Diameter—$\frac{1}{16}$ in., $\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{5}{32}$ in., $\frac{3}{16}$ in., $\frac{7}{32}$ in., $\frac{1}{4}$ in., $\frac{5}{32}$ in. and $\frac{5}{16}$ in.

Length—14 inches.

Blue Tag denotes Electrodes. Ends of rods colored blue.

Yellow Tag for Welding Rods

PAGE-ARMCO WELDING RODS and ELECTRODES

Blue Tag for Electrodes

Specifications—Welding material is one of the most important elements in the Welding process. Great care is exercised in the selection of the parent or base metal, of welding equipment and welder. To be consistent, this same care should be used in selecting welding materials. Metallurgy distinctly proves that certain elements are detrimental and it is only logical to assume that dependable welding material should be as free as possible from these injurious elements. Page-Armco Electrodes conform in all respects to the American Welding Society Welding Wire Specifications Grade E-No. 1-A and Page-Armco Gas Welding Rods to G-No. 1-A.

Important Factors—Scientific methods of production and scientific research are absolute essentials in the manufacture of high quality welding material. Page-Armco Welding Rods and Electrodes possess these factors, first in the production of Armco Ingot Iron and then the processing of this metal into wire. The American Rolling Mill Co. and the Page Steel & Wire Co. together have developed the highest quality Welding Iron in the world for the welding of mild steel parts.

PAGE HIGH CARBON

GAS WELDING RODS AND ELECTRODES

Page High Carbon Electrode Deposit Hardness Analysis

Scleroscope

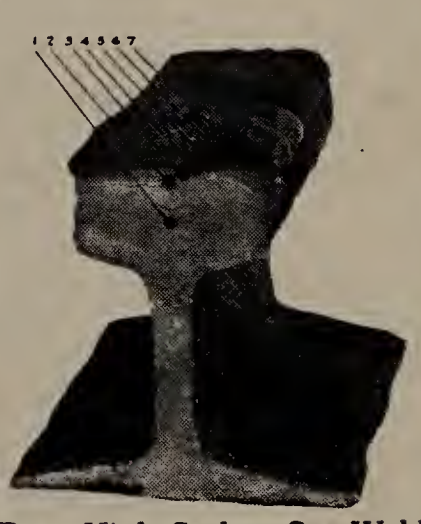
No.	
1	(Original Metal).....30
2	34
3	33
4	35
5	37
6	38

The manufacture and reclaiming of High Carbon Steel parts by welding can best be accomplished by the use of suitable welding metal. The data presented herewith is typical of results secured with Page High Carbon Gas Welding Rods and Electrodes, and indicates qualities more than equal to the original metal.

Conform in all respects to A. W. S. specifications, E-No. 1-C.

Look for red tag, and red-colored ends.

Red Tag for High Carbon Welding Wire



Page High Carbon Gas Weld Deposit Hardness Analysis

Scleroscope

No.	
1	(Original Metal).....30
2	31
3	31
4	32
5	33
6	35
7	37

PAGE STEEL AND WIRE CO.

An Associate Company of the American Chain Co., Inc.

BRIDGEPORT, CONN.

FACTORIES

ADRIAN, MICH. **MONESSEN, PA.**

SALES OFFICES

Chicago **New York** **Pittsburgh** **San Francisco**

The Prest-O-Lite Company, Inc.

General Offices
Carbide and Carbon Building, 30 East 42nd Street, NEW YORK CITY
In Canada, Prest-O-Lite Company of Canada, Ltd., TORONTO

Prest-O-Lite
DISSOLVED ACETYLENE

One Gas That Meets Every Requirement of Welders and Cutters

In spite of continuous efforts to substitute other fuel gases, Acetylene remains today the **only practical welding gas** and by far the **best for cutting.**

Because it is so perfectly adapted to both welding and cutting, it does away with the necessity for two stocks of fuel gas and two types of apparatus for cutting and welding.

One supply of gas answers every demand. Operators using one fuel gas and one type of apparatus become more efficient and problems of management are simplified.

Its Portability an Advantage

The oxy-acetylene welder's hand-truck is the ambulance of the modern machine shop. Instantly accessible, quickly and easily wheeled to any part of the shop, wherever the job may be—the oxy-acetylene outfit saves thousands of dollars by eliminating delay and reclaiming broken parts.

Prest-O-Lite Dissolved Acetylene has made possible the use of a highly pure gas in an easily portable and economical form.

Delivery Service

A great chain of Prest-O-Lite distributing stations has been built up with the view to meeting every possible requirement of Prest-O-Lite users. It embraces a total of 58 plants and warehouses located in every industrial center throughout the country.

How Prest-O-Lite Is Supplied

Prest-O-Lite is supplied in two size cylinders. Style "WC" of approximately 100 cu. ft. capacity, and Style "WK" of approximately 300 cu. ft. capacity. Prest-O-Lite is distributed under a system whereby the holder of an exhausted cylinder may promptly exchange it for another Prest-O-Lite of like size, fully charged and ready for use.

When a Prest-O-Lite cylinder is exhausted of its acetylene contents, send it or take it to the nearest Distributing Station (see list on opposite page) and receive a full one in exchange, upon payment of a moderate exchange fee.

An ever increasing number of new cylinders are being distributed from Prest-O-Lite's cylinder factory to meet the constantly enlarging demand for Prest-O-Lite service.

Making cylinders to our own design, guarding every step, Prest-O-Lite knows that each cylinder measures up to its high standard resulting from years of experience in the manufacture and distribution of Dissolved Acetylene.

Advice on Uses of the Process

We are interested in not only helping you solve some tough individual problem, but in opening up new applications of Acetylene Using Processes.

Every Prest-O-Lite user looks to his nearest District Sales Office (see list below) for help, cooperation and advice on any matter involved in the use of Acetylene. An inquiry will bring you information concerning our latest sales and service plans.

How to Order Prest-O-Lite

While distributing stations for Prest-O-Lite are maintained in every manufacturing district in the country, each user should communicate with his nearest Prest-O-Lite District Sales Office for arrangements to adequately cover his requirements. Special prices are extended where substantial quantities of Prest-O-Lite are required at regular intervals. Prices are quoted F. O. B. Prest-O-Lite distributing points. Users prepay transportation charges when returning "empties." Prest-O-Lite District Sales Offices are located in the following cities:

Prest-O-Lite Company, Inc.

Atlanta	Los Angeles
Baltimore	Milwaukee
Boston	New Orleans
Buffalo	New York
Chicago	Philadelphia
Cleveland	Pittsburgh
Dallas	San Francisco
Detroit	Seattle
Kansas City	St. Louis

SHIPPING POINTS FROM WHICH PREST-O-LITE MAY BE ORDERED

Your order should be forwarded addressed to "THE PREST-O-LITE COMPANY, INC.," at any of the following Distributing Stations (* indicates Plant).

DISTRIBUTING STATIONS

ALABAMA
Birmingham...12th So. 20th St.

COLORADO
Denver.....So. Broadway & Exposition Ave.

DISTRICT OF COLUMBIA
Washington.....
Maryland Ave. & 8th St., S. W.

GEORGIA
*Atlanta.....23 Kuhrt St.

ILLINOIS
Chicago.....321 Alexander St.
East Peoria.....
.....721 So. Washington St.
East St. Louis....700 Broadway

INDIANA
*Hammond....P. O. Box 225, C. I. & L. Ry. & Marble St.
*Speedway..(Near Indianapolis)
Terre Haute....541 No. 5th St.

IOWA
*Davenport .....
P. O. Box 387, 500 S. Howell St.
*Des Moines.....
..P. O. Box 852 S. W. 7th St.

KANSAS
Wichita.....115 No. Mead St.

KENTUCKY
Louisville.....128 E. Main St.

LOUISIANA
*New Orleans..4120 Toulouse St.

MARYLAND
*Baltimore.....
.....Franklin Post Office Sta.
*Elkton.....P. O. Box 57

MASSACHUSETTS
*Cambridge .....
Concord Ave. & B. & M. Track
*Indian Orchard.....
(Near Springfield) Oak St. Station (B. & A. R. R.)

MICHIGAN
*Detroit.....7301 Clayton Ave.
Grand Rapids.....
.....500 Shawmut St., N.W.

MINNESOTA
*Duluth....350 E. First Ave., E.
*St. Louis Park...(Near Minneapolis) Lake & Monitor Sts.

MISSOURI
Kansas City..1811 Wyandotte St.
*North Kansas City.....
.....12th & Charlotte St.
*St. Louis.....4018 Duncan Ave.

NEBRASKA
*Omaha.....P. O Box 1154, Ave. H. & I. & C. R. R.

NEW YORK
*Buffalo.....
....Colgate & Germania Sts.
New York City.637 West 50th St.
Utica....Walnut & Schuyler Sts.

NEW JERSEY
*Newark.....351 Doremus Ave.

OHIO
Canton..638 Mulberry Road, S.E.
*Cincinnati....P. O. Box 37, Stock Yards, C. H. & D. & Dempsey Ave.
*Cleveland....1792 LaMoille St.
Columbus.....320 Dublin Ave.
Toledo.....414 S. Erie St.
Youngstown.....601 Jones St.

OKLAHOMA
Tulsa.....1 No. Boulder St.

PENNSYLVANIA
Allentown.....311 Gordon St.
Philadelphia .....
.....18th & Cambria Sts.
*Pittsburgh.Lincoln & Tabor Sts.

TEXAS
*Dallas .....P. O. Box 1011, 1304 S. Austin St.
Galveston.....2308 Avenue C
Houston .....
Live Oak St. & H. B. & T. R. R.

VIRGINIA
Norfolk.Colonial Ave. & 22nd St.
*Richmond

WEST VIRGINIA
Charleston .....
..Pine St. & Pennsylvania Ave.

WISCONSIN
*Milwaukee.619 Trowbridge Ave

PACIFIC COAST

CALIFORNIA
*Los Angeles .....
P. O. Box 596, El Monte Road
Oakland.....400 Alice St.
San Diego.....426 A St.
San Francisco.....
.....8th & Brannon Sts.
*So. San Francisco

OREGON
Portland.....15th & Hoyt Sts.

UTAH
Salt Lake City..118 West 2nd St.

WASHINGTON
*Seattle .....East Marginal Way & County Line
Spokane.....162 So. Post St.

No Acetylene user, large or small, should close an arrangement for acetylene supply without first securing 1923 prices from our nearest District Sales Office.

ELECTRIC "RACO" OXY-ACETYLENE

MILD STEEL and IRON WELDING WIRES

"RACO" BLUE LABEL

Analysis:

Carbon	not more than 0.18%
Manganese	not more than 0.60%
Phosphorus	not more than 0.025%
Sulphur	not more than 0.04%
Silicon	not more than Trace

This wire is admirably suited for all general repair and production work. For welding mild steel, structural shapes, plates, bars or low carbon steel forgings and castings. It is unusually smooth in finish and free from any trace of grease or rust.

The steel from which "Raco" Electric Welding Wire is manufactured is made by the basic open hearth process and the wire is drawn with great care to insure evenness in structure.

"RACO" WHITE LABEL

Analysis:

Carbon	not more than 0.06%
Manganese	not more than 0.30%
Phosphorus	not more than 0.02%
Sulphur	not more than 0.04%
Silicon	not more than Trace

This wire may be used with success wherever imported Norwegian or Swedish wire has been considered necessary.

"RACO" COVERED YELLOW LABEL

Analysis:

Carbon	not more than 0.18%
Manganese	not more than 0.60%
Phosphorus	not more than 0.025%
Sulphur	not more than 0.04%
Silicon	not more than Trace

"RACO" Covered Electrodes are used with either alternating or direct current where bare wires will not give satisfactory results.

"RACO" HIGH CARBON

Analysis:

Carbon	0.85-1.10%
Manganese	0.30-0.60%
Phosphorus	not more than 0.04%
Sulphur	not more than 0.04%
Silicon	not more than 0.04%

for welding with direct current high carbon steel and worn surfaces where great resistance to abrasive wear is desired such as rails, frogs, switch points, bearing surfaces, etc.

"RACO" HIGH CARBON COVERED

Analysis:

Carbon	0.85-1.10%
Manganese	0.30-0.60%
Phosphorus	not more than 0.04%
Sulphur	not more than 0.04%
Silicon	not more than 0.04%

for welding with alternating current high carbon steel and worn surfaces where great resistance to abrasive wear is desired, such as rails, frogs, switch points, bearing surfaces, etc.

"RACO" RED LABEL

Analysis:

Carbon	not more than 0.06%
Manganese	not more than 0.30%
Phosphorus	not more than 0.02%
Sulphur	not more than 0.04%
Silicon	not more than Trace

"RACO" MILD STEEL RODS FOR OXY-ACETYLENE WELDING
Copper Coated

Answers the usual railroad, shipyard and industrial requirements as are allowed by authoritative regulating bodies such as the American Bureau of Shipping, the Interstate Commerce Commission, etc.

Colored labels in this style identify each different kind of RACO WIRE.

The Reid-Avery Company produces "Raco" Welding Wires *only*. It has no other welding interests. This fact in itself is a guarantee of quality and satisfactory service.

The steel from which "Raco" Wires are made is produced by the basic open hearth process.

The analyses presented here, and which may be thoroughly depended upon, make it possible to standardize on one or two wires for all, or practically all, uses.

Each package bears a tag plainly indicating customer's requisition and order numbers as well as grade and size of wire.

Inspection may be made either at our plant or at destination as may be most convenient.

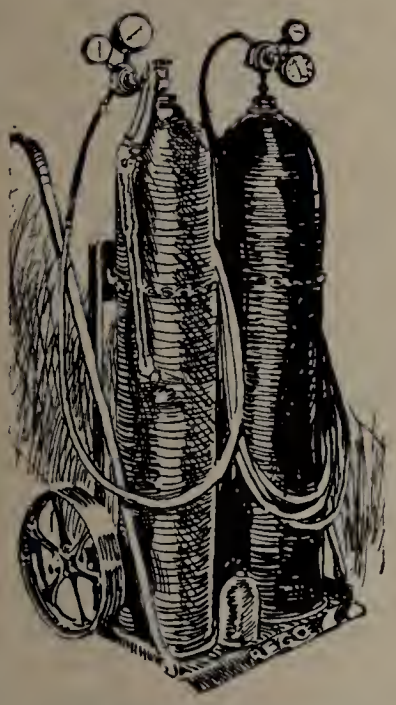
"Raco" Wires are uniformly well finished—bare wires are smooth and absolutely free from grease or rust. Coverings, where used, are carefully baked on to insure permanency.

Samples for testing and descriptive booklet sent promptly

REID-AVERY COMPANY

21st Street and Washington Avenue
Philadelphia, Pa.

High Grade Materials Are Essential To High Grade Work

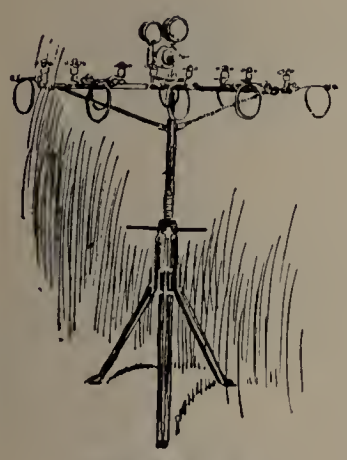


RECO PORTABLE OUTFITS

WE maintain a complete stock of quality apparatus, gases and supplies for welding and cutting.

OXYGEN, Acetylene and Hydrogen that insures strong welds and clean cuts.

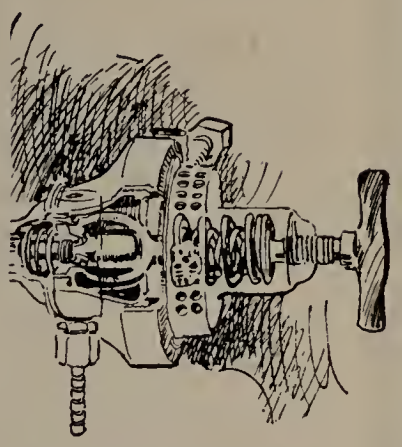
APPARATUS — the well known REGO line (see pages 366 to 370) of welding and cutting equipment. Torches Regulators, Gauges, Trucks, Generators, Complete Outfits for every use, all backed by the REGO reputation for Economy, Dependability and Performance.



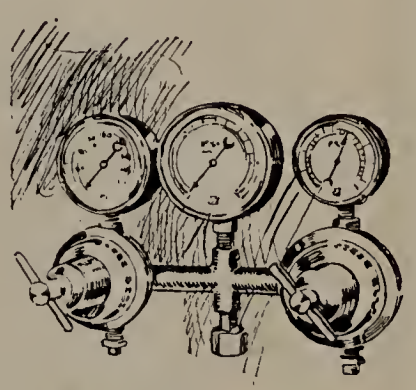
TANK MANIFOLDS

FLUXES, Welding Rods, Carbide, Asbestos Paper and other supplies of recognized standard and at attractive prices.

Consult us on your problems.



REGO REGULATOR DETAILS



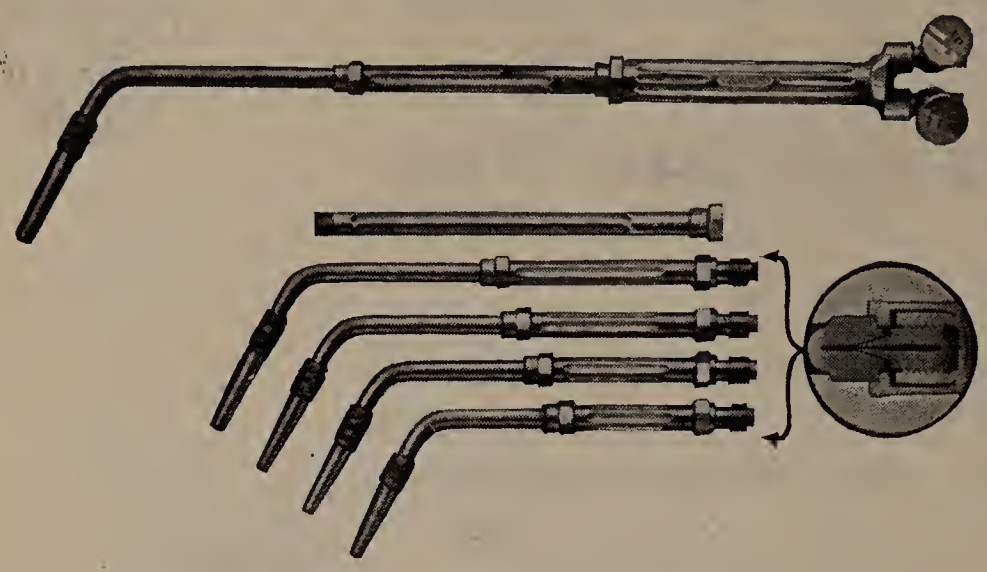
MANIFOLD REGULATOR

SOUTHERN OXYGEN CO.

Plant
South Washington, Va.

Warehouse
Hagerstown, Md.

The Latest Word in Torch Development



Smith's No. 6 Welding Torch

With **SMITH'S No. 6 WELDING TORCH** you have as many different length torches as you have tip assemblies. By adding the 9" fluted brass extension which comes with Smith's No. 6 Welding Torch, you have double the number of length torches that you have tip assemblies, ALL FOR THE PRICE OF ONE TORCH.

SMITH'S No. 6 WELDING TORCH is made up of a fluted brass handle 8" long and a series of tip assemblies. Each tip assembly is made up of a fluted brass section (which contains a mixing nozzle) and a long heavy pure drawn copper (not composition) bar (drilled) which extends to the tip end which is also made of pure drawn copper, not composition.

Copper, next to gold, is the best conductor of heat and this long pure drawn copper bar or extension draws the heat away from the tip or tip end and dissipates it into the air, thus preventing the tip from overheating. Most of our competitors use brass or a copper alloy which is a much poorer conductor of heat than copper.

SMITH'S No. 6 WELDING TORCH has **no explosion chamber** and therefore it does not splatter molten metal over the operator. Our mixing chamber, which extends from the mixing nozzle to the tip end, is the same diameter throughout, thus eliminating any chance for gas pockets which cause popping and backfiring.

Each individual tip assembly has its own individual mixing nozzle which is the correct size for each indivdual tip assembly.

The tip assembly for **SMITH'S No. 6 WELDING TORCH** has but one seat and can be screwed into the handle with ease. They seat themselves readily.

The hole in **SMITH'S No. 6 WELDING TORCH** tip is the same diameter throughout and for that reason can be filed or dressed off and used indefinitely without changing the size of the flame.

SMITH'S No. 6 WELDING TORCH can be adjusted to accommodate a right or left handed welder.

SMITH'S No. 6 WELDING TORCH comes regularly equipped with five tip assemblies Nos. 1, 3, 5, 7, 9, one 9" fluted brass extension that can be used with any of the tip assemblies on very hot jobs. We make tips for this torch up to size 12.

LENGTH OF SMITH'S No. 6 WELDING TORCH WITH DIFFERENT TIP ASSEMBLIES

(Including Handle)

No. 1 Tip Assembly, over all	13½"
No. 2 Tip Assembly, over all	13½"
No. 3 Tip Assembly, over all	14½"
No. 4 Tip Assembly, over all	15"
No. 5 Tip Assembly, over all	16½"
No. 6 Tip Assembly, over all	17½"
No. 7 Tip Assembly, over all	18¾"
No. 8 Tip Assembly, over all	19½"
No. 9 Tip Assembly, over all	22"
No. 10 Tip Assembly, over all	24"
No. 11 Tip Assembly, over all	28½"
No. 12 Tip Assembly, over all	30"
LENGTH OF HANDLE	8"
Length of Extension	9"
Length of 600 Cutting Tip assembly with handle over all	20"

Ask Your Nearest Jobber, or Inquire of Us Direct.

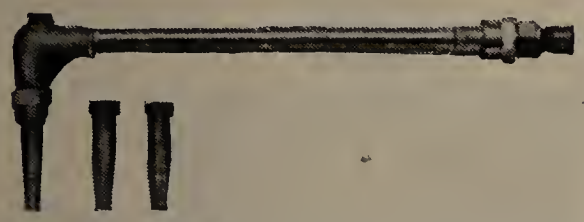
SMITH'S INVENTIONS INCORPORATED

2633 4th Street S. E.

Minneapolis :: :: Minnesota

Special Tips for Smith's No. 6 Torch

Smith's Cutting Tip Assembly For No. 6 Welding Torch



Smith's No. 600 Cutting Tip Assembly is interchangeable with the welding tips. This cutting head has a maximum cutting capacity of 6" and is furnished regularly with one cutting tip, No. 602, unless otherwise specified. No. 601 has a cutting capacity of 1", No. 602 a cutting capacity of 2½" and No. 603 a cutting capacity of 6".

Smith's No. 64C Cylinder Tip

(For Use with Smith's No. 6 Welding Torch)

This is the tip for the expert welder, the man who prides himself on being able to do what the other fellow can't. This is the tip that the welder doing cylinder work has perhaps thought of, but never seen.

Smith's No. 64C Cylinder Tip was built to get into small places, the places that cannot be reached with the ordinary welding torch or tips.

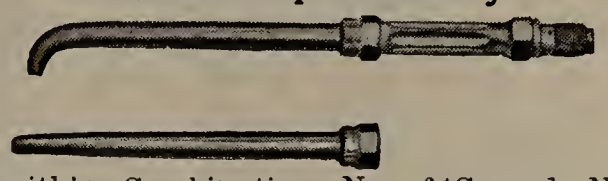
Smith's No. 64C Cylinder Tip is interchangeable with the welding tips for Smith's No. 6 Welding Torch only, and cannot be used with any other make of torch.

Smith No. 64S (Straight Tip)

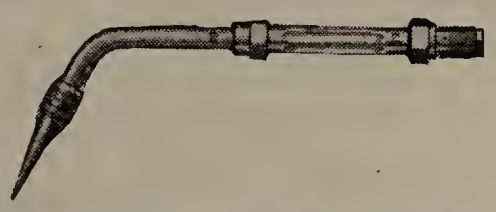
Similar in every respect to Smith No. 64C (cylinder tip) but is perfectly straight and can be used for welding in even smaller places than can be reached with the No. 64C.

Especially adapted for use in boiler work and cylinder heads.

Smith's Combination No. 64C and No. 64S Tip Assembly



Smith's Combination No. 64C and No. 64S Tip Assembly consists of a No. 64C (cylinder tip) assembly and a No. 64S (straight) tip end, these tip ends being interchangeable.



No. 60 Smith Lead Burning Tip Assembly for No. 6 Torch

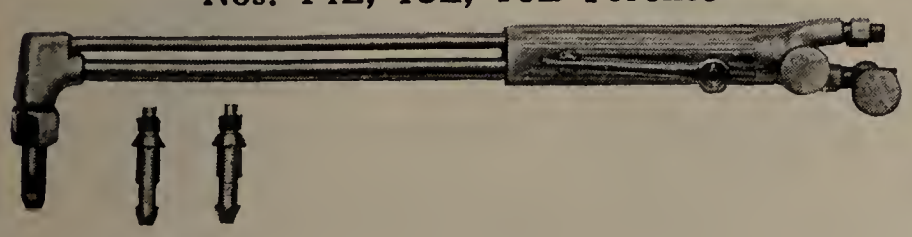
This special tip for Lead Burning is interchangeable with the welding tips for No. 6 Torch. It is about the length of No. 61 welding tip but the tip end is more slender. The flame from this tip is long and needle-like, suitable for battery work.

No. 60CB Carbon Burning Tip for No. 6 Torch

A special tip, interchangeable with the welding tips for No. 6 torch. Fitted with 15-in. detachable copper tube which is slender and flexible admitting of access through any spark plug hole.

Smith's Cutting Torch

Nos. 14L, 15L, 16L Torches



A fast and economical cutting torch exceptionally efficient for free hand steel cutting and in wrecking and scrapping. In piercing holes this Smith torch has no equal.

The torch continues to work after the end of tip is burned off. For heavy work you cannot beat it. Has five interchangeable tips made of pure copper. Is furnished with lever type oxygen jet control. Fitted with a right angle, straight line or 70° head as desired.

SMITH'S INVENTIONS INCORPORATED

Ask Your Nearest Jobber, or Inquire of Us Direct.

2633 4th Street S. E.

Minneapolis :: :: Minnesota

Smith's Automatic
ACETYLENE GENERATORS

The merit and dependability of the Smith Generator have been proven by years of successful shop service. This generator produces acetylene at one-third of its cost in drums. The automatic motor keeps the gas forming in the generator as rapidly or as slowly as the reserve supply is used.

Made in 4 Sizes

Depending on the volume of work in your shop there is one size of Smith's Generator to exactly meet your needs. They are made in 30-50-100 and 200 pound carbide capacities.

Smith's Welding Equipment

is a complete line of standard oxy-acetylene welding equipment—from generators to smallest torch.

Smith's 100 lb. Generator.

Ask Your Nearest Jobber, or Inquire of Us Direct.

SMITH'S INVENTIONS INCORPORATED

2633 4th Street S. E.
Minneapolis :: :: Minnesota

SMITH'S Cast Iron Soldering Outifit

Smith's Cast Iron Solder is made for repairing castings of all kinds, but is especially useful in repairing cracked motor blocks, cracked cylinder heads and cracked or scored cylinders. It may also be used by the foundryman in plugging holes and flaws in castings.

No preheating is necessary, which eliminates the possibility of warping and distorting.

Smith's Cast Iron Solder will greatly increase the earning capacity of the shop and build a reputation for prompt and satisfactory repairs at a moderate price. One of the great values of Smith's Cast Iron Solder lies in the ease with which motor repairs can be accomplished. In many cases scored cylinders and cracked water jackets can be repaired without removing the engine from the chassis and in no case is it necessary to dismantle the engine if the part for repair is in an accessible location.

Smith's Cast Iron Soldering Outfit consists of:
1 Smith Acetylene Soldering Iron.
1 Regular 1-lb. Soldering Bit.
1 Radiator Soldering Bit.
1 Hatchet Shaped Soldering Bit.
1 6-ft. length Hose and Connections.
1 Prest-O-Lite Lighting Tank Connection.
2 Lbs. Smith's Cast Iron Solder.
1 Can Soldering Powder.
1 Carrying Case.
1 Directions for use.

Smith's Pre-Heating Torch

Eliminate bothersome charcoal fires in pre-heating work! Here is a torch that throws a flame from a foot to four feet in length, using kerosene or fuel oil. No delay in generating; lights like city gas.

SMITH'S INVENTIONS INCORPORATED

Ask Your Nearest Jobber, or Inquire of Us Direct.

2633 4th Street S. E.
Minneapolis :: :: Minnesota

A. D. DORMAN, Pres. and Treas.
D. R. HOFFMAN, Sec'y.

SS STEEL SALES CORPORATION

J. A. ROESCH, JR., Vice-Pres.
F. W. WALTERS, Gen'l Sales Mgr.

WELDING RODS
OF QUALITY
FOR

Gas **NORWELD** Welding

Electric **ELECWELD** Arc

TOUGH

Cast **CASTWELD** Iron

Tobin **BRONZEWELD** Equivalent

DUCTILE

Alloyed **VANADWELD** Vanadium

Chrome **NICKELWELD** Nickel

STRONG

Track **HICARWELD** Welding

Steel **STEELWELD** Castings

WELDS

Each of the welding rods have been carefully selected for your particular class of welding, and represents a proven quality. Many of the largest and most critical welders in the country have been convinced, and now specify them exclusively. Send us your next order as a trial. We are certain you will specify our brands in the future.

Quantity production makes our prices lowest.
(See following page for list of our products)

STEEL SALES CORPORATION

Jefferson and Adams Streets, Chicago, Ill.

QUALITY SERVICE GUARANTEED

Steel of Every Description

DIRECT STEEL MILL REPRESENTATIVES

BRASS, COPPER AND OTHER METALS

Western Representatives for

Superior Steel Corporation
Harrow Spring Company
Kidd Drawn Steel Company
Copper Clad Steel Company
Bordentown Steel & Tube Corporation
Allegheny Steel Co.
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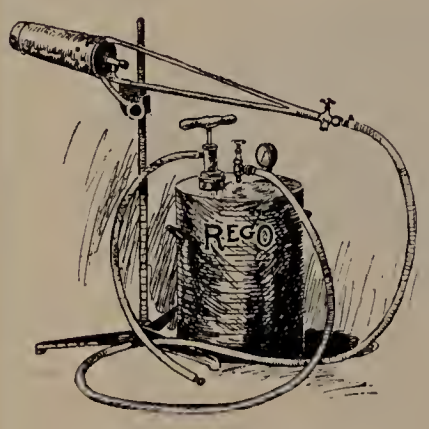

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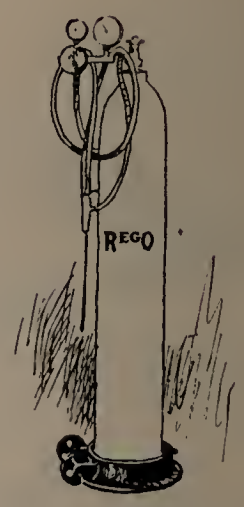

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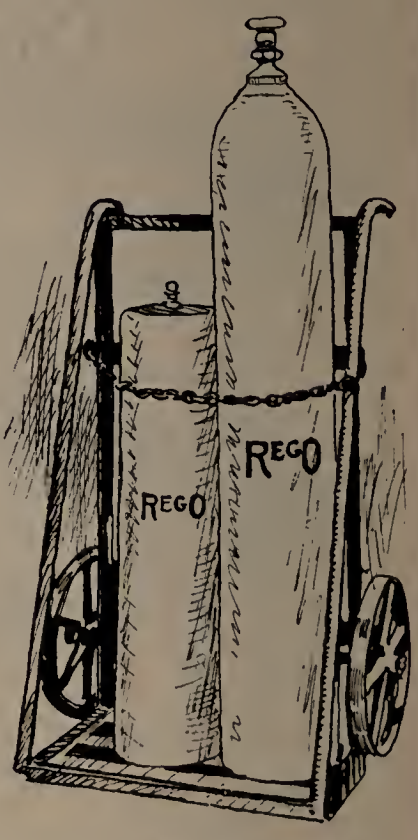

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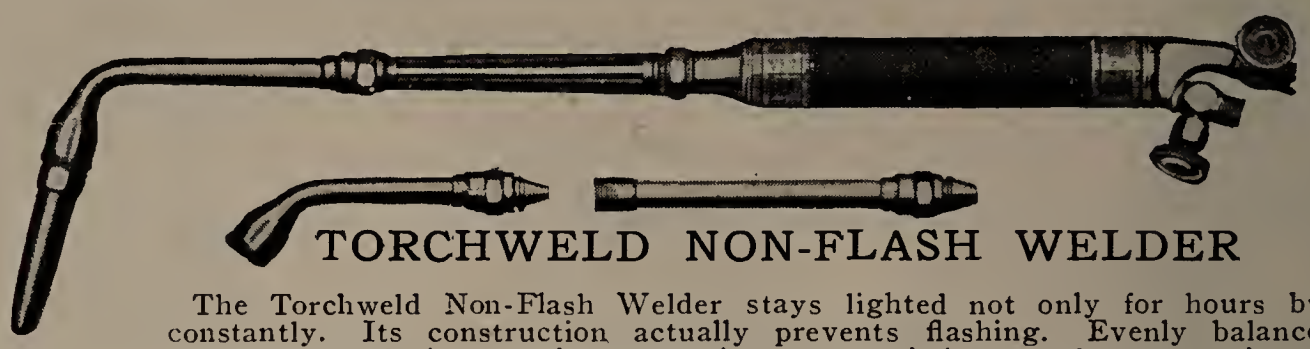

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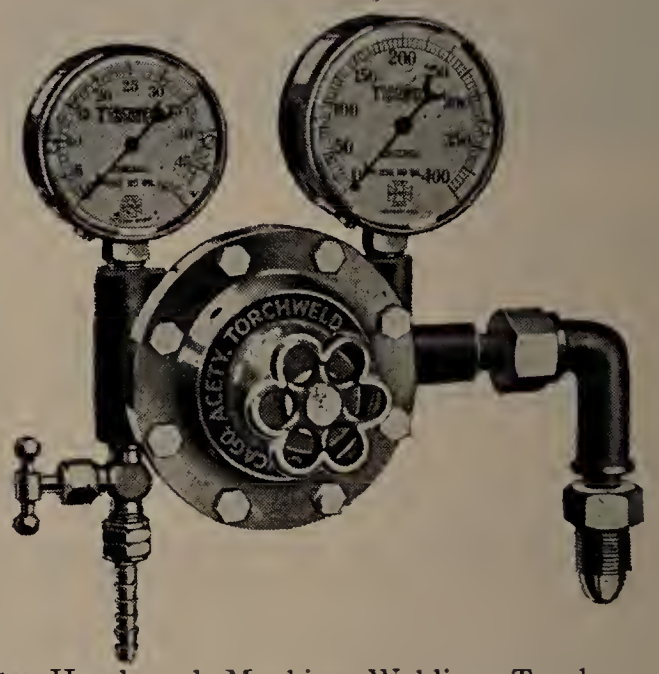

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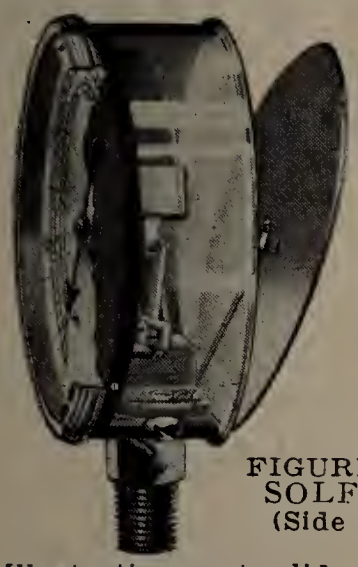
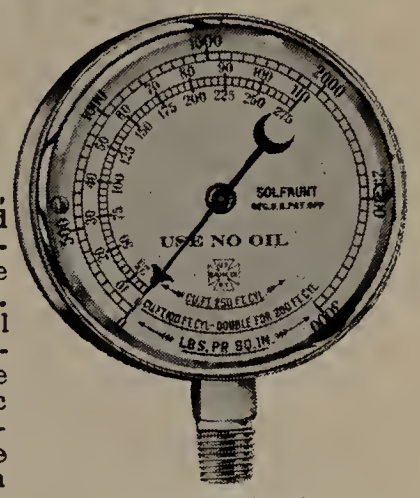


FIGURE 546A
SOLFRUNT
(Side View)

Illustrating cast solid front and full release safety back.

3½" SOLFRUNT
Figure 546A (high pressure)

Cast brass case and ring, size 3½-in., dial furnished with cubic foot scales, percent scale or pressure scale only; ¼-in. pipe connection. The outside figures on dial represent the pounds pressure per square inch—the middle line shows the cubic contents of 100 and 200-foot cylinders. The inside figures are for use with 250-foot cylinders only.



(Front View)

2½-inch SOLFRUNT
Figure 600 (high pressure)

Cast brass case and ring, size 2½-inch, 180° arc, dial furnished with cubic foot scales, percent scale or pressure scale only. ¼-inch pipe connection.

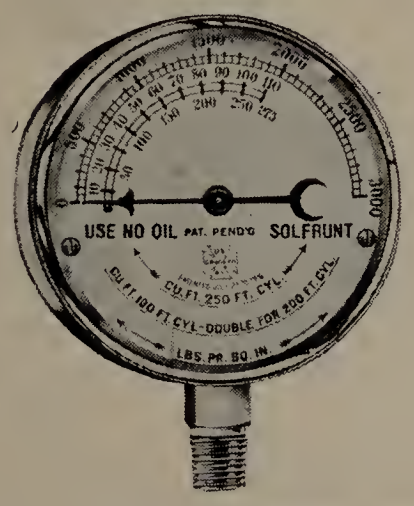


FIGURE 600

Both No. 546A and No. 600 have solid cast front and full release back.

In mounting high pressure Oxygen gauges do not use white lead or any substance of a greasy or oily nature, as it may cause an explosion.

For pressures of 500 lbs. or less

FIGURE 602

HIGH PRESSURE ACETYLENE

Cast brass case and ring; standard finishes; made in 3-inch size; standard graduations 400 and 500 lbs. ¼-inch male pipe connection.

For tank pressures approximating 250 lbs.

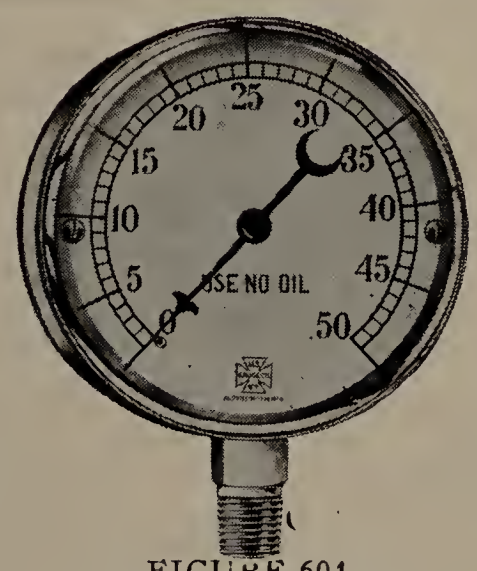


FIGURE 604
LOW PRESSURE
ACETYLENE OR OXYGEN

Cast brass case and ring; standard finishes; made in 2½-inch size; standard dial graduations 30, 50, 100, 200 and 300 lbs. ¼-inch male pipe connection. **Designed particularly for low pressure. Suitable for use in conection with any gas on welding or cutting work.**

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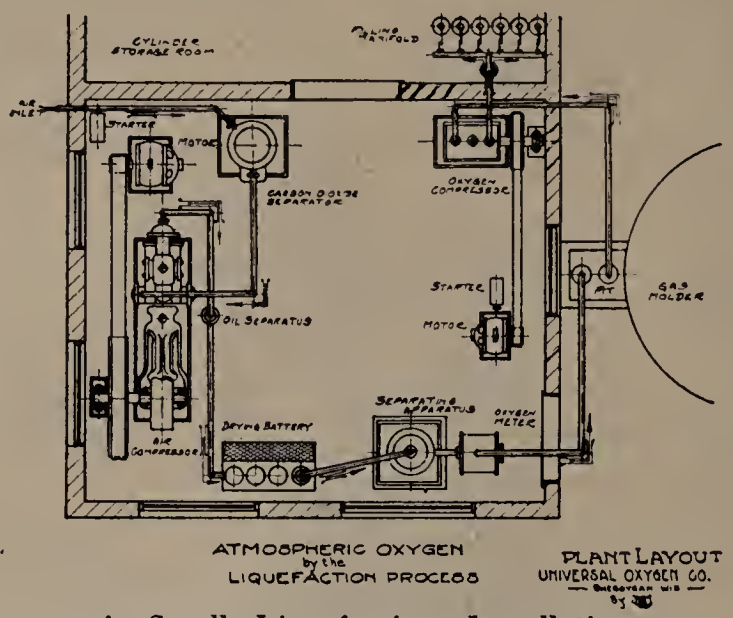

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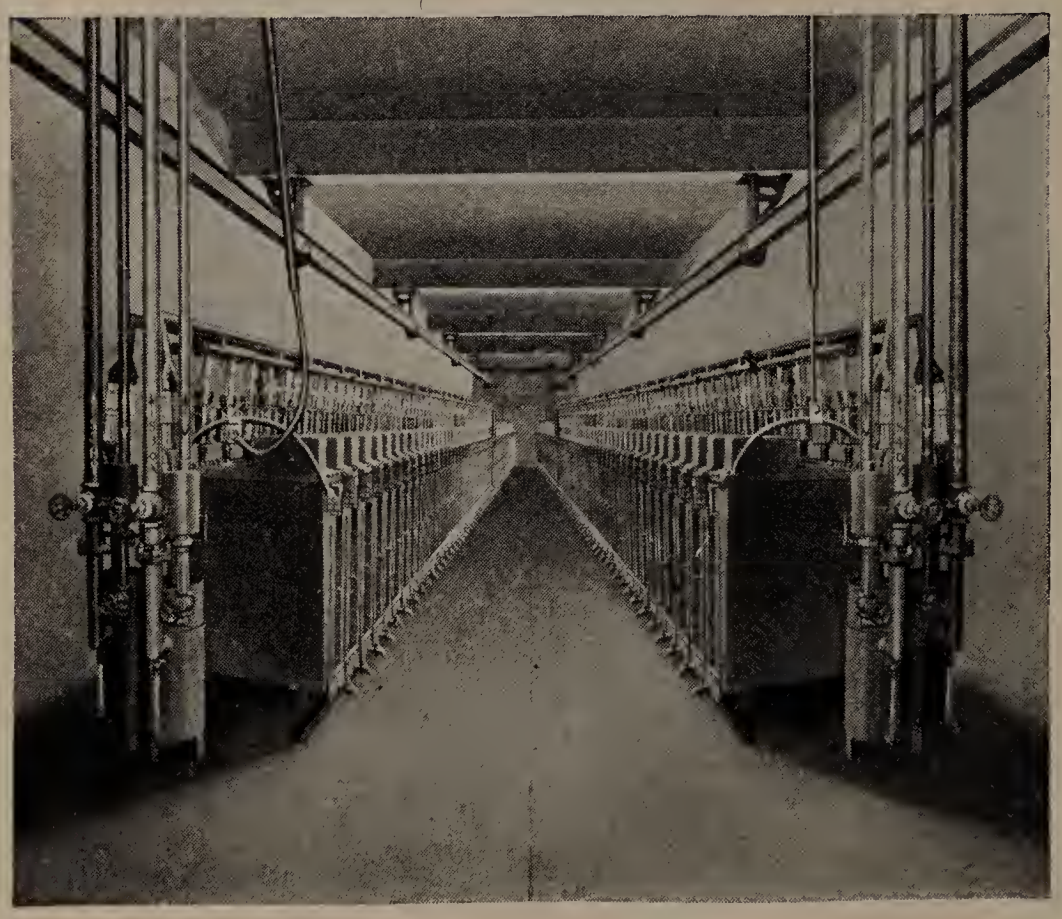

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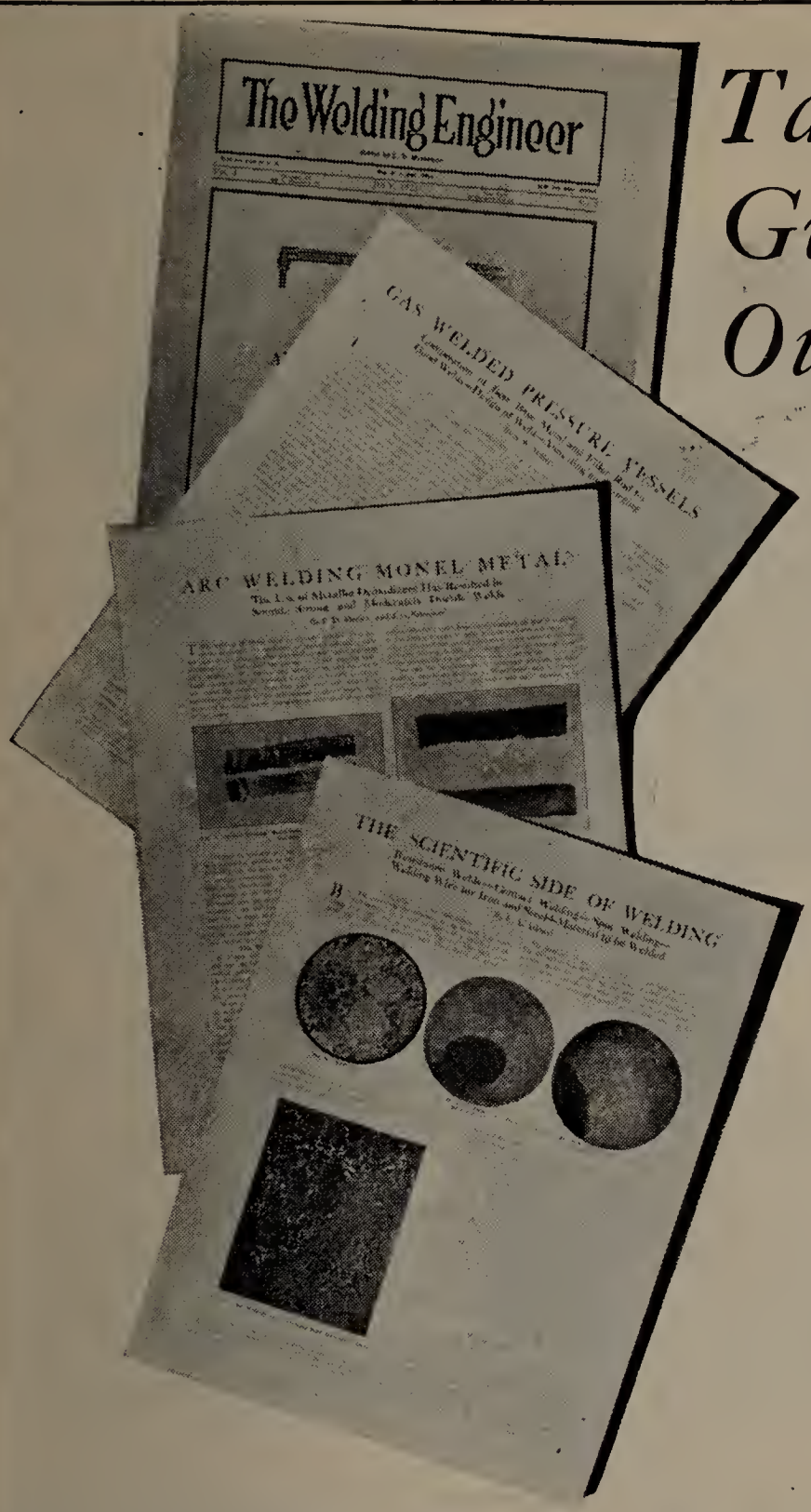

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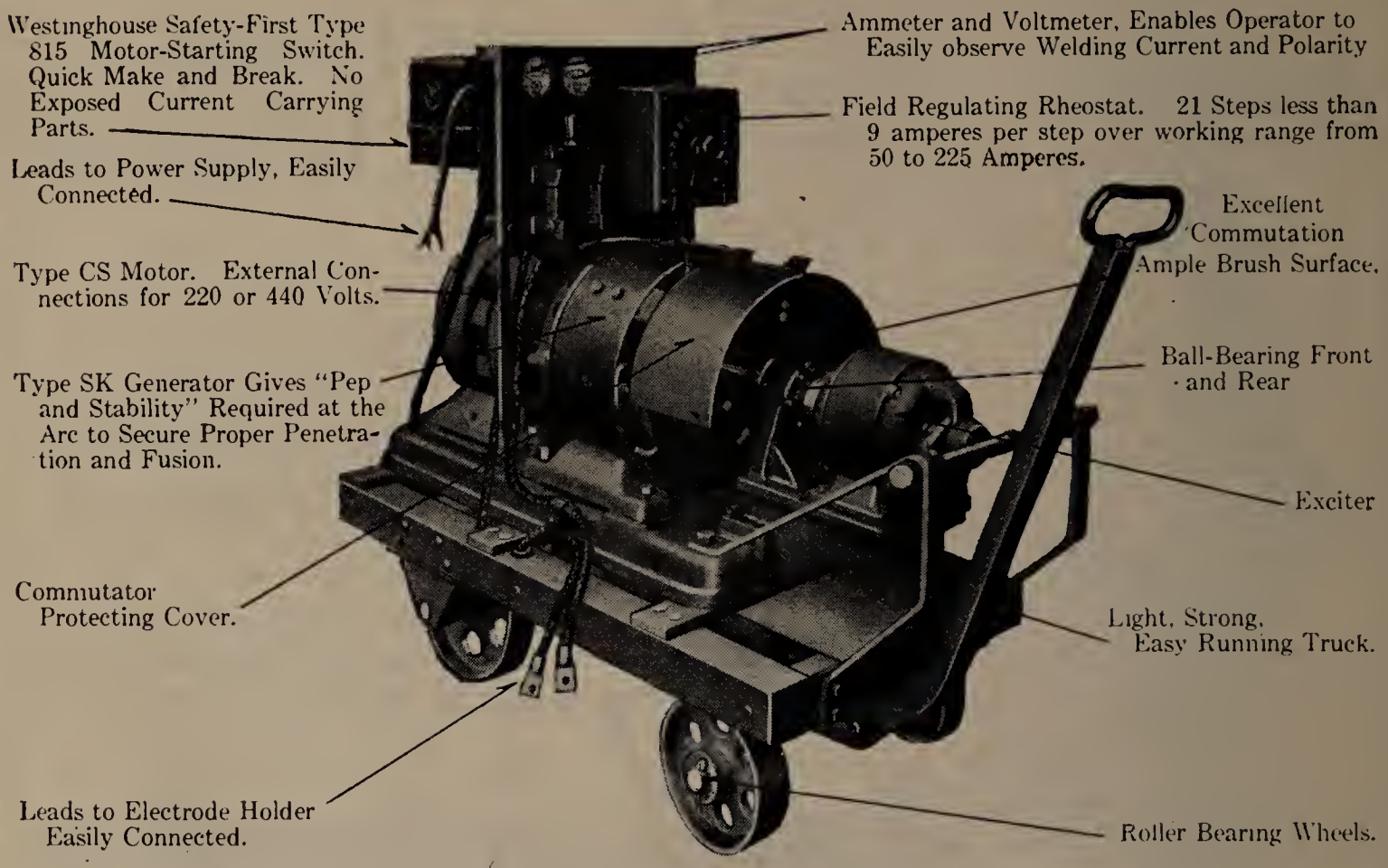

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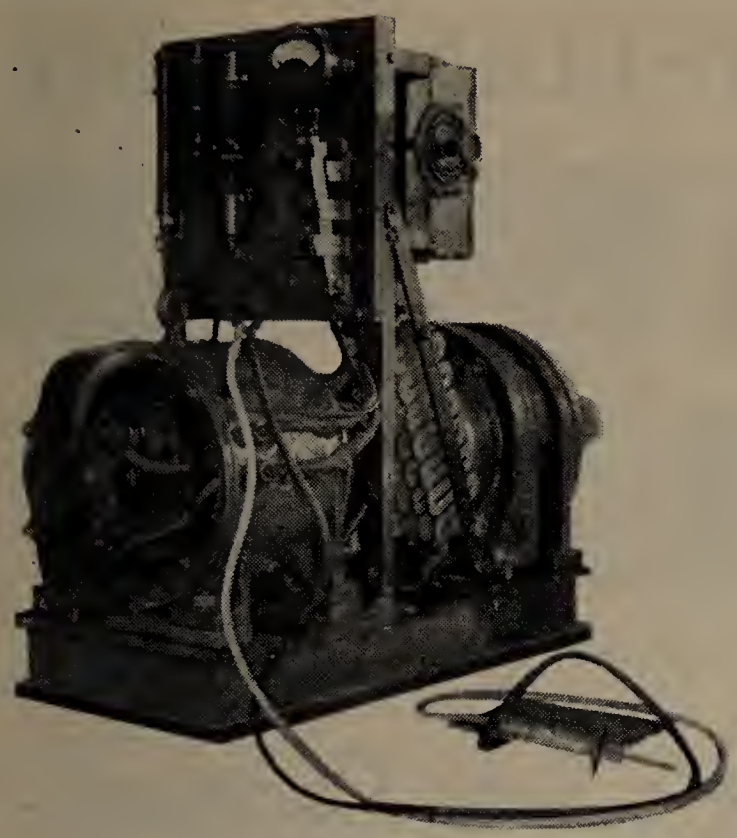

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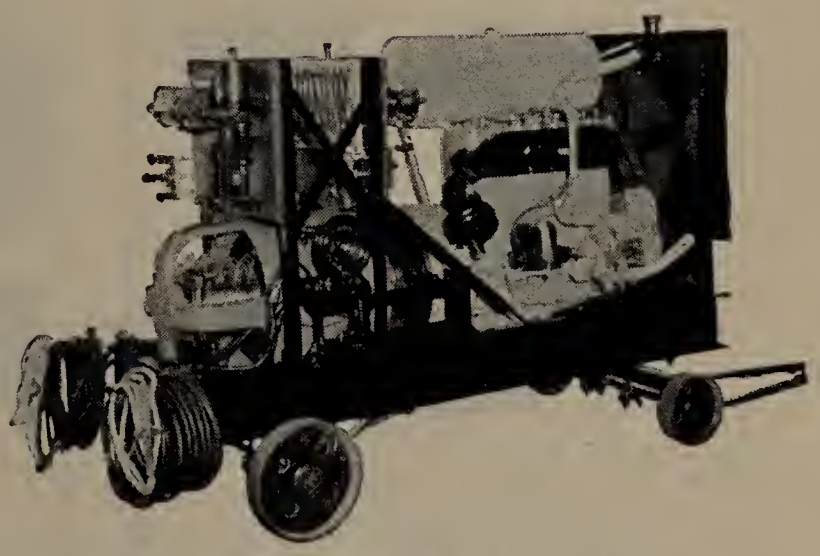

Standard 2 Arc Gasoline Engine Driven Unit

Wilson Welder and Metals Co.

132 King Street, New York, U. S. A.

ROEBLING WELDING WIRE

FOR GAS AND ELECTRIC WELDING

John A. Roebling's Sons Company

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BOSTON, 93-95 Pearl Street
CHICAGO, 165 West Lake Street
PHILADELPHIA, 223 Arch Street
PITTSBURGH, Sandusky & Robinson Sts., N. S.
CLEVELAND, 701 St. Clair Avenue, N. E.
ATLANTA, 69 Walton Street
SAN FRANCISCO, 624-646 Folsom Street
LOS ANGELES, 216 South Alameda Street
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SEATTLE, 900 First Avenue, South

This Mark on Welding or Cutting equipment insures efficiency, long life and satisfaction.

Welding Plants,
Cutting Apparatus,
Lead Burning Outfits,
Acetylene Generators,
Welders Accessories.

U.S.

Welding equipment designed and built to order. New ideas developed and resulting apparatus manufactured. Quotations furnished without charge.

"U. S." Welding Apparatus manufactured exclusively by The United States Welding Co., Inc., Minneapolis, Minn., U. S. A.

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Experience has taught us that it is an easy matter to secure subscriptions to *The Welding Engineer,* when the attention of the right party is secured.

Welders need good, authentic information about welding. We pay a liberal commission to Agents.

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The Welding Engineer
608 S. Dearborn St. Chicago

Anti-Borax WELDING FLUX

OXY-ACETYLENE or ELECTRIC WELDING and BRAZING FLUXES are BEST BY EVERY TEST

Free samples for every metal upon request.

Use "E-Z" when forge welding, and be happy.

Manufactured only by
ANTI-BORAX COMPOUND COMPANY
Fort Wayne :: Indiana

E. G. LUENING
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CHICAGO

Consultant in the proper construction, selection and operation of gas producing plants and in the proper and economical uses of industrial gases.

Particularly experienced in electrolytic oxygen and hydrogen plants.

The Ideal Face Shield

For Electric Welders, Cutters, Etc.

THE Ideal Face Shields are constructed of Aluminum and Vulcanized Fibre, resulting in durability and minimum weight.

Manufactured and Sold by

The Ideal Face Shield Company

Columbus, Ohio

ROL-MAN

MANGANESE STEEL WELDING RODS

For Electric Welding **For Gas Welding**

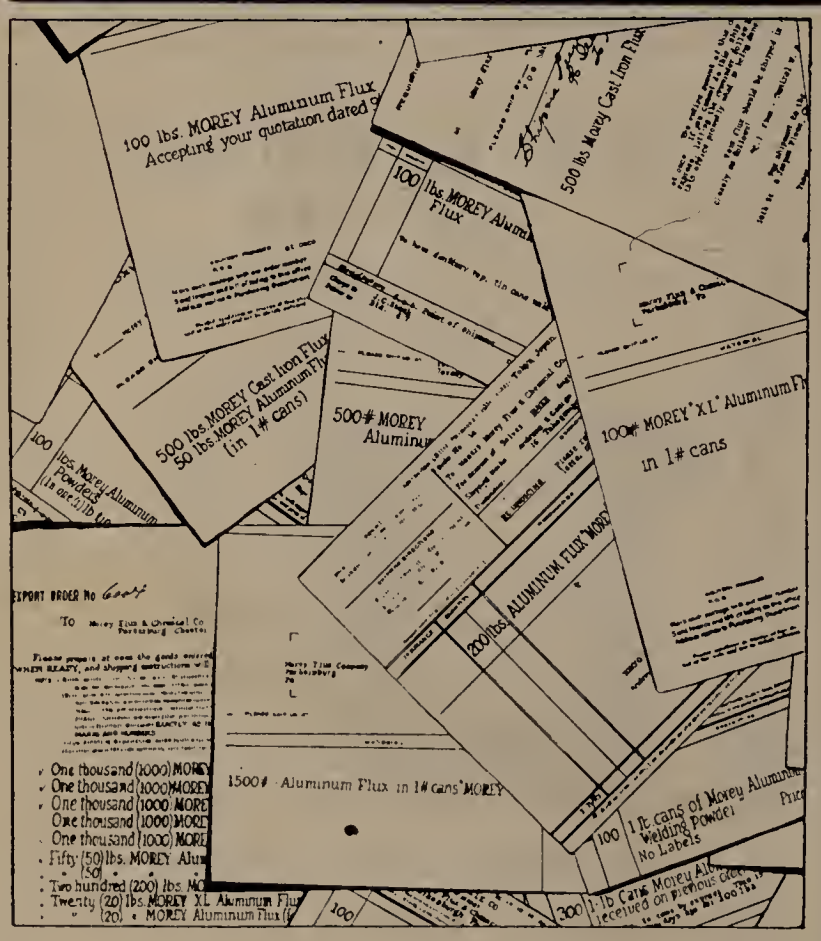
MANGANESE 12 to 15 per cent

Build Up a **TRUE MANGANESE STEEL** Wearing Surface with **ROL-MAN RODS** on Worn Manganese and Carbon, Crossings, Frogs, Switches and Track-work. Crusher parts, Dredge-Bucket Lips, Sprocket and Gear Teeth, Rolls, etc.

ROL-MAN MANGANESE for MAXIMUM WEAR

STANDARD SIZES AND LENGTHS—COATED OR BARE SAMPLES ON REQUEST

MANGANESE STEEL FORGE CO. **PHILADELPHIA, PA.**



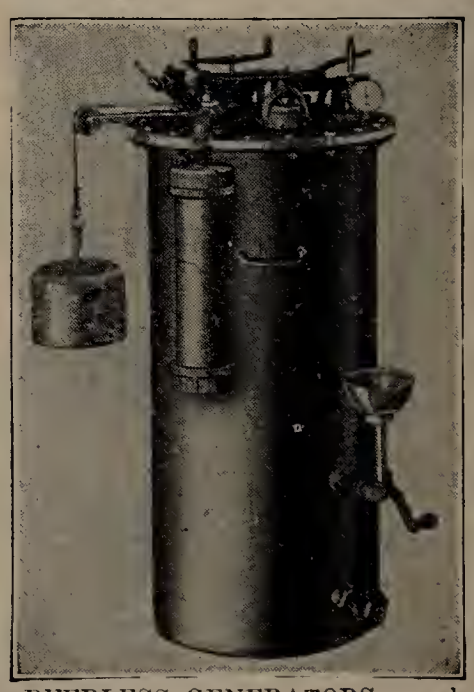
Orders representing tons of

"MOREY FLUX"

Used by the World's Prominent Oxy-Acetylene Welders.

MOREY FLUX & CHEMICAL CO.

Parkesburg, Pa. **U. S. A.**



WELDING AND CUTTING TORCHES, SPECIAL BRASS PARTS, CARBON BURNING AND LEAD BURNING OUTFITS, CAST IRON—STEEL—BRASS AND ALUMINUM RODS, HOSE, FLUXES AND GOGGLES, REGULATORS AND GAUGES, WELDING AND CUTTING OUTFITS, ELECTRIC DRILLS AND GRINDERS

PEERLESS GENERATORS, as shown, are built in four sizes:

Carbide capacity	Cu. ft. of gas	Price
10-lb.	50 cu. ft.	$100.00
15-lb.	75 cu. ft.	110.00
20-lb.	100 cu. ft.	130.00
25-lb.	125 cu. ft.	150.00

(Allowance on acetylene tanks)

These Generators are PORTABLE, can be moved from one place to another, weighing about 135 lbs.

AUTOMATIC, equipped with the CELEBRATED SUPERIOR FEED.

GENERATES gas for about $1.20 per 100 cu. ft.

Batteries—Lead Molds—Post Builders—Lead Pots—Plate Burning Racks—Stencil Letters and Figures—Trucks—Preheaters.

Write for complete catalog.

SUPERIOR OXY-ACETYLENE MACHINE COMPANY

HAMILTON, OHIO, U. S. A.

We repair all makes of Torchs, Regulators and Gauges.

BUYERS' INDEX

Readers of The Welding Encyclopedia will find this index to contain the most accurate information obtainable relating to welding apparatus and supplies. The Catalog Section includes the principal manufacturers of the United States.

ACETYLENE (Compressed in Cylinders)
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*Commercial Acetylene Supply Co.
*Gas Products Co.
Gas Tank Recharging Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
*Memphis Oxygen Co.
*Noble Co.
*Prest-O-Lite Co.
*Purox Co.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Universal Oxygen Co.

ACETYLENE GENERATORS
*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Carbic Mfg. Co.
*Gas Products Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
*Memphis Oxygen Co.
*Oxweld Acetylene Co.
*Smith's Inventions, Inc.
*St. Paul Welding Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

ALUMINUM FILLER RODS
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*Gas Products Co.
*General Welding & Eqpt. Co.
The Imperial Brass Mfg. Co.
*Kentucky Oxygen-Hydrogen Co.
*Noble Co.
*Oxweld Acetylene Co.
*St. Paul Welding Co.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Mach. Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

ALUMINUM FLUX
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Anti-Borax Compound Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Gas Products Co.
*General Welding & Eqpt. Co.
The Imperial Brass Mfg. Co.
*Kentucky Oxygen-Hydrogen Co.
*Morey Flux & Chemical Co.
*Noble Co.
*Oxweld Acetylene Co.
*St. Paul Welding Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

ALUMINUM SOLDER
*Wm. Cramp & Sons.

ANNEALING FURNACES
Buffalo Dental Mfg. Co.
*General Electric Co.
*Universal Oxygen Co.

APRONS (Asbestos)
*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Chicago Eye Shield Co.
*Electric Arc Cutting & Welding Co.
*Smith's Inventions, Inc.

ASBESTOS GLOVES
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
*Chicago Eye Shield Co.

ASBESTOS SHEET PAPER
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
*Gas Products Co.
Imperial Brass Co.
*Memphis Oxygen Co.,
*Noble Co.
*Oxweld Acetylene Co.
*St. Paul Welding Co.
*Smith Inventions, Inc.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

BLOW TORCHES (Acetylene)
See "Torches"

BOOKS (Relating to Welding)
*The Welding Engineer

BRASS AND BRONZE FLUX
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*Gas Products Co.
The Imperial Brass Mfg. Co.
*Kentucky Oxygen-Hydrogen Co.
*Noble Co.
*Oxweld Acetylene Co.
*Smith's Inventions, Inc.
*St. Paul Welding Co.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

BRASS SPELTER WIRE
*Air Reduction Sales Co.
*Burdett Mfg. Co.
*Torchweld Equipment Co.
*Universal Oxygen Co.

*See Table of Contents, Catalog Section, Page 362.

BRAZING OUTFITS
*General Welding & Equipment Co.
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
Buffalo Dental Mfg. Co.
*Carbic Mfg. Co.
*Gas Products Co.
*Harris Calorific Co.
*Memphis Oxygen Co.
*Noble Co.
*Purox Co.
*Smith's Inventions, Inc.
*St. Paul Welding Co.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.

BRONZE FILLER RODS
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*Electric Arc Cutting & Welding Co.
*Gas Products Co.
The Imperial Brass Mfg. Co.
*Kentucky Oxygen-Hydrogen Co.
Modern Engineering Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Southern Oxygen Co.
*Steel Sales Corp.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

CABLE (For Leads)
*Electric Arc Cutting & Welding Co.
*General Electric Co.
*Gibb Instrument Co.
*Lincoln Electric Co.
*Westinghouse Elec. & Mfg. Co.
*Wilson Welder & Metals Co.

CARBIDE (Calcium)
American Carbolite Sales Co.
Gas Tank Recharging Co.
Shawinigan Products Corp.
Standard Carbide Sales Co.
*Union Carbide Sales Co.

CARBIDE (Compressed in Cakes)
*Carbic Mfg. Co.

CARBON (Blocks, Paste, Etc.)
National Carbon Co.
*U. S. Welding Co.

CARBON REMOVING TORCHES
See "Torches"

CAST IRON FILLER RODS AND FLUX
*Acme Oxygen Co.
*Air Reduction Sales Co.
*Anti-Borax Compound Co.
Bierman-Everett Fdy. Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*Electric Arc Welding & Cutting Co.
*Gas Products Co.
*General Welding & Equip. Co.
Hauck Mfg. Co.
Imperial Brass Mfg. Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
Modern Engineering Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Reid-Avery Co.
*John A. Roebling's Sons Co.
*Southern Oxygen Co.
*St. Paul Welding Co.
*Smith's Inventions, Inc.
*Steel Sales Corp.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

CONSULTING ENGINEERS
*E. G. Luening.

CONTRACT WELDING
*Buckeye Welding & Supply Co.
*Wilson Welder & Metals Co.

CUTTING RODS (Elec. Arc)
*Electric Arc Cutting & Welding Co.

CYLINDERS
Wm. Wharton, Jr., & Co.

ELECTRIC ARC WELDING OUTFITS
*Electric Arc Welding & Cutting Co.
*General Electric Co.
*Gibb Instrument Co.
*Lincoln Elec. Co.
Quasi Arc Weldtrode Co.
Siemund Wenzel Co.
U. S. Light & Heat Corporation.
*Westinghouse Elec. & Mfg. Co.
*Wilson Welder & Metals Co.

ELECTRODE HOLDERS
*Electric Arc Welding & Cutting Co.
*General Electric Co.
*Gibb Instrument Co.
*Lincoln Electric Co.
Quasi-Arc Weldtrode Co.
Siemund Wenzel Co.
U. S. Light & Heat Corporation.
*Westinghouse Elec. & Mfg. Co.
*Wilson Welder & Metals Co.

ELECTROLYTIC OXYGEN AND HYDROGEN GENERATING EQUIPMENT
*Burdett Oxygen Co.
*International Oxygen Co.
*National Oxygen Co.
*Universal Oxygen Co.

FILLER RODS (Aluminum)
*Acme Oxygen Co.
*Air Reduction Sales Co.
Bierman-Everett Fdy. Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*Electric Arc Cutting & Welding Co.
Hauck Mfg. Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
Modern Engineering Co.
*St. Paul Welding Co.
*Steel Sales Corp.
*Torchweld Equipment Co.
*United States Welding Co.

FILLER RODS (Swedish Iron)
*Acme Oxygen Co.
*Air Reduction Sales Co.
Bermo Supply Co.
Bierman-Everett Fdy. Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*Electric Arc Cutting & Welding Co.
Hauck Mfg. Co.
The Imperial Brass Mfg. Co.
*Kentucky Oxygen-Hydrogen Co.
Modern Engineering Co.
*Oxweld Acetylene Co.
*Page Steel & Wire Co.
*Reid-Avery Co.
*John A. Roebling's Sons Co.
*Steel Sales Corp.
*Superior Oxy-Acetylene Machine Co.
*Universal Oxygen Co.

FILLER RODS (Bronze)
*Acme Oxygen Co.
*Air Reduction Sales Co.
Bierman-Everett Fdy. Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*General Welding & Equip. Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
Modern Engineering Co.
*Oxweld Acetylene Co.
*Reid-Avery Co.
*John A. Roebling's Sons Co.
*Steel Sales Corp.
*Superior Oxy-Acetylene Machine Co.

*See Table of Contents, Catalog Section, Page 362.

*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

FILLER RODS (Vanadium Steel)

*Acme Oxygen Co.
*Air Reduction Sales Co.
Bermo Supply Co.
Bierman-Everett Fdy. Co.
*Burdett Mfg. Co.
*Central Steel & Wire Co.
*Wm. Cramp & Sons.
*General Welding & Equip. Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
Modern Engineering Co.
*Oxweld Acetylene Co.
*Reid-Avery Co.
*Steel Sales Corp.
*Superior Oxy-Acytelene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

FLUE WELDERS (Electric)

*General Electric Co.

FLUXES

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Anti-Borax Compound Co.
*Bettendorf Oxygen Co.
*Carbic Mfg. Co.
*Central Steel & Wire Co.
*Gas Products Co.
Imperial Brass Co.
*K-G Welding & Supply Co.
*Kentucky Oxygen-Hydrogen Co.
*Memphis Oxygen Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*St. Paul Welding Co.
*Universal Oxygen Co.

FURNACES (Annealing)

Buffalo Dental Mfg. Co.
*General Electric Co.
Hauck Mfg. Co.
*Universal Oxygen Co.

PREHEATING FURNACES

Buffalo Dental Mfg. Co.
Giest Mfg. Co.
Hauck Mfg. Co.

GAS BURNER (Preheating)

*Air Reduction Sales Co.
*Superior Oxy-Acetylene Machine Co.
*Universal Oxygen Co.

GAUGES

*U. S. Gauge Co.

GENERATORS (Oxygen or Hydrogen)

*Burdett Mfg. Co.
*International Oxygen Co.
*National Oxygen Co.
*Universal Oxygen Co.

GLOVES (Welders Asbestos)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
*Electric Arc Cutting & Welding Co.
Imperial Brass Co.
*International Oxygen Co.
*Torchweld Equipment Co.

GOGGLES

*Acme Oxygen Co.
*Bastian-Blessing Co.
*Bettendorf Oxygen Co.
*Carbic Mfg. Co.
*Chicago Eye Shield Co.
*Gas Products Co.
*Memphis Oxygen Co.
*Noble Co.
*Purox Co.
*Southern Oxygen Co.
*St. Paul Welding Co.

GRINDING MACHINES

Wodack Electrical Tool Corporation

HARDENING FURNACES

Buffalo Dental Mfg. Co.
*General Electric Co.
Hauck Mfg. Co.

HOSE (Oxygen and Acetylene)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
Buffalo Dental Mfg. Co.
*Gas Products Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
*K-G Welding & Cutting Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Smith's Inventions, Inc.
*St. Paul Welding Co.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

HOSE UNIONS

*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Burdett Mfg. Co.
*Gas Products Co.
*Harris Calorific Co.
Hauck Mfg. Co.
Imperial Brass Mfg. Co.
*International Oxygen Co.
*K-G Welding & Cutting Co.
*Memphis Oxygen Co.
*Noble Co.
*Purox Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*Universal Oxygen Co.

HYDROGEN GENERATING APPARATUS

*Burdett Mfg. Co.
*International Oxygen Co.
*Universal Oxygen Co.

HYDROGEN

*Acme Oxygen Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Gas Products Association
*International Oxygen Co.
*Memphis Oxygen Co.
*Purox Co.
*Swift & Co.

KEROSENE PREHEATING TORCHES

*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
Hauck Mfg. Co.
*Memphis Oxygen Co.
*St. Paul Welding Co.
*Oxweld Acetylene Co.
*Smith's Inventions, Inc.
*Superior Oxy-Acetylene Machine Co.

NEEDLE VALVES

*Air Reduction Sales Co.
*The Bastian-Blessing Co.
Buffalo Dental Mfg. Co.
*Burdett Oxygen Co.
Federal Brass Works.
*Gas Products Co.
*General Welding & Equip. Co.
*Harris Calorific Co.
The Imperial Brass Mfg. Co.
*K-G Welding & Cutting Co.
*Memphis Oxygen Co.
*Noble Co.
*Purox Co.
*St. Paul Welding Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*Universal Oxygen Co.

*See Table of Contents, Catalog Section, Page 362.

NITROGEN

*Air Reduction Sales Co.
*Linde Air Products Co.
*International Oxygen Co

OIL BURNERS (Preheating)

*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*The Imperial Brass Mfg. Co.
Modern Engineering Co.
*Oxweld Acetylene Co.
*St. Paul Welding Co.
*Superior Oxy-Acetylene Machine Co

OXYGEN (Compressed in Cylinders)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Gas Products Assn.
*Gas Products Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
*The Linde Air Products Co.
*Memphis Oxygen Co.
*Purox Co.
*Southern Oxygen Co.
*Swift & Co.
*Universal Oxygen Co.

OXYGEN GENERATING PLANTS (Air Liquefaction Process)

H. Amling.
*Groen Mfg. Co.
*M Keith Dunham.
*International Oxygen Co.
*Universal Oxygen Co.

OXYGEN AND HYDROGEN GENERATING EQUIPMENT

*Burdett Oxygen Co.
*Gas Products Assn.
*International Oxygen Co.
*National Oxygen Co.
*Universal Oxygen Co.

PRESSURE GAUGES

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bastian & Blessing Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
*Gas Products Co.
*General Welding & Equipment Co.
Federal Brass Works
*Harris Calorific Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*Memphis Oxygen Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*St. Paul Welding Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*U. S. Gauge Co.
*United States Welding Co.
*Universal Oxygen Co.

PUBLICATIONS

*The Welding Engineer
*The Welding Encyclopedia

REGULATING VALVES (Acetylene)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*The Bastian-Blessing Co.
*Bettendorf Oxygen Co.
*Carbic Mfg. Co.
*Burdett Mfg. Co.
Federal Brass Works
*Gas Products Co.
*General Welding & Equipment Co.
*Harris Calorific Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*K-G Welding & Cutting Co.
*Memphis Oxygen Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*St. Paul Welding Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

REGULATING VALVES (Hydrogen)

*Acme Oxygen Co.
*Bettendorf Oxygen Co.
*The Bastian-Blessing Co.
*Burdett Mfg. Co.
Federal Brass Works
*Gas Products Co.
*General Welding & Equipment Co.
*Harris Calorific Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*K-G Welding & Cutting Co.
*Memphis Oxygen Co.
Modern Engineering Co.
*Noble Co.
*Purox Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
St. Paul Welding Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*Universal Oxygen Co.

REGULATING VALVES (Oxygen)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*The Bastian-Blessing Co.
*Bettendorf Oxygen Co.
*Gas Products Co.
*General Welding & Equipment Co.
*Harris Calorific Co.
Imperial Brass Mfg. Co.
*Memphis Oxygen Co.
*Noble Co.
*Smith's Inventions, Inc.
*Oxweld Acetylene Co.
*Purox Co.
*Southern Oxygen Co.
*St. Paul Welding Co.
*Universal Oxygen Co.

SOLDERS

*Wm. Cramp & Sons.

TORCHES (Oxy-Acetylene Welding and Cutting)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*The Bastian-Blessing Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
Federal Brass Works
*Gas Products Co.
*General Welding & Eqpt. Co.
*Harris Calorific Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
*K-G Welding & Cutting Co.
*Memphis Oxygen Co.
Modern Engineering Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*St. Paul Welding Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

TORCHES (Oxy-Hydrogen Welding and Cutting)

*Acme Oxygen Co.
*The Bastian Blessing Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
Federal Brass Works
*Gas Products Co.
*General Welding & Eqpt. Co.
*Harris Calorfic Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*K-G Welding & Cutting Co.
*Memphis Oxygen Co.

*See Table of Contents, Catalog Section, Page 362.

Modern Engineering Co.
*Noble Co.
*Purox Co.
*Smith's Inventions, Inc.
*Southern Oxygen Co.
*St. Paul Welding Co.
*Superior Oxy-Acetylene Machine Co
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

SEAM WELDERS (Electric)

*General Electric Co.
*Gibb Instrument Co.

TANK CONNECTIONS (Oxygen and Acetylene Adapters)

*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Burdett Mfg. Co.
*Gas Products Co.
*Harris Calorific Co.
*International Oxygen Co.
*Memphis Oxygen Co.
*Noble Co.
*Purox Co.
*Smith's Inventions, Inc.
*Superior Oxy-Acetylene Machine Co.
The Imperial Brass Mfg. Co.
*Torchweld Equipment Co.
*Universal Oxygen Co.

THERMIT WELDING

*Metal & Thermit Corp.

TORCHES (Gasoline and Kerosene Preheating)

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
Buffalo Dental Mfg. Co.
*Burdett Mfg. Co.
Federal Brass Works
*Gas Products Co.
*Harris Calorific Co.
Hauck Mfg. Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*Kentucky Oxygen-Hydrogen Co.
*Memphis Oxygen Co.
Modern Engineering Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Smith's Inventions. Inc.
*Southern Oxygen Co.
*St. Paul Welding Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

TRUCKS (Cylinder Carriers)

*Air Reduction Sales Co.
*The Bastian-Blessing Co.
*Burdett Mfg. Co.
The Imperial Brass Mfg. Co.
Modern Engineering Co.
*Superior Oxy-Acetylene Machine Co.
*Torchweld Equipment Co.
*United States Welding Co.
*Universal Oxygen Co.

VALVES (For Oxygen Cylinders)

*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Burdett Mfg. Co.
*International Oxygen Co.
*Universal Oxygen Co.

WELDING APPARATUS (Electric)

*Electric Arc Welding & Cutting Co.
*General Electric Co.
*Gilt Instrument Co.
*Lincoln Elec. Co.
Siemund-Wenzel Co.
U. S. Light & Heat Corporation.
*Westinghouse Elec. Mfg. Co.
*Wilson Welder & Metals Co.

WELDERS' GLOVES

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
*Carbic Mfg. Co.
*Chicago Eye Shield Co.
*Electric Arc Cutting & Welding Co.
*International Oxygen Co.
The Imperial Brass Mfg. Co.
*Universal Oxygen Co.

WELDERS' GOGGLES

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bastian-Blessing Co.
*Bettendorf Oxygen Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
*Chicago Eye Shield Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
Modern Engineering Co.
*Oxweld Acetylene Co.
*St. Paul Welding Co.
*Universal Oxygen Co.

WELDERS' MASKS

*Chicago Eye Shield Co.
*Electric Arc Welding and Cutting Co.
*General Electric Co.
*Gibb Instrument Co.
*Ideal Face Shield Co.
*Lincoln Electric Co.

WELDING RODS AND WIRE

*Acme Oxygen Co.
*Air Reduction Sales Co.
*Bettendorf Oxygen Co.
Bierman-Everett Fdy. Co.
*Electric Arc Cutting & Welding Co.
*Burdett Mfg. Co.
*Carbic Mfg. Co.
*Central Steel & Wire Co.
*William Cramp & Son.
*Federal Tool & Alloy Steel Corp.
*Gas Products Co.
*Gibb Instrument Co.
The Imperial Brass Mfg. Co.
*International Oxygen Co.
*Kentucky Oxy-Acetylene Co.
*Manganese Steel Forge Co.
*Memphis Oxygen Co.
Modern Engineering Co.
*Noble Co.
*Oxweld Acetylene Co.
*Purox Co.
*Page Steel & Wire Co.
*Reid-Avery Co.
*John A. Roebling's Sons Co.
Siemund-Wenzel Co.
*St. Paul Welding Co.
*Southern Oxygen Co.
*Steel Sales Corporation.
*Torchweld Equipment Co.
Transportation Engineering Co.
*Universal Oxygen Co.
*Wilson Welder & Metals Co.

WIRE AND CABLE (Asbestos Insulated)

*Central Steel & Wire Co.
*D. & W. Fuse Works, General Electric Co.

*See Table of Contents, Catalog Section, Page 362.

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